FISH LAKE, INDIANA

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A FINAL FEASIBILITY REPORT

SUBMITTED TO

FISH LAKE PROPERTY OWNERS ASSOCIATION

BY

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MAY 1990

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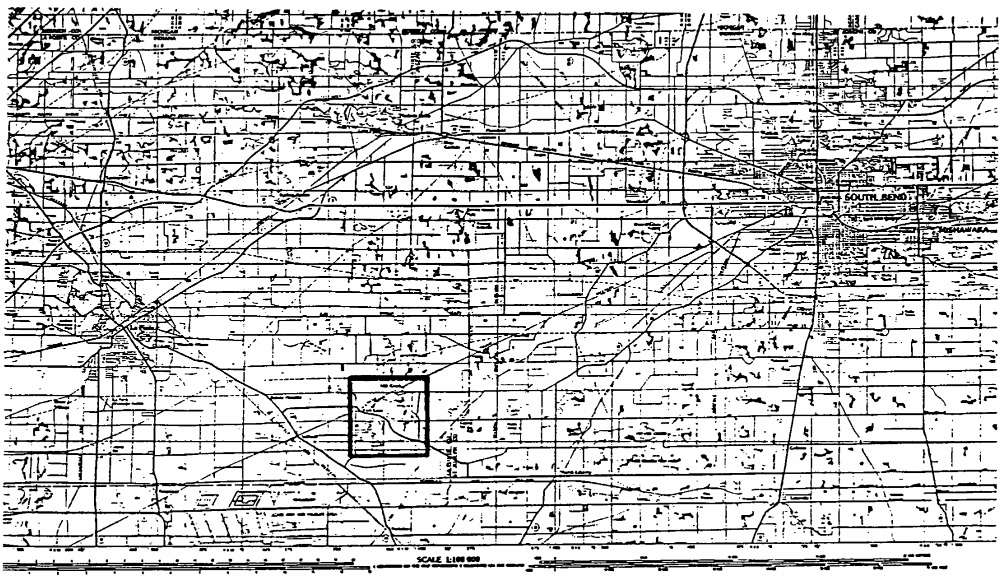
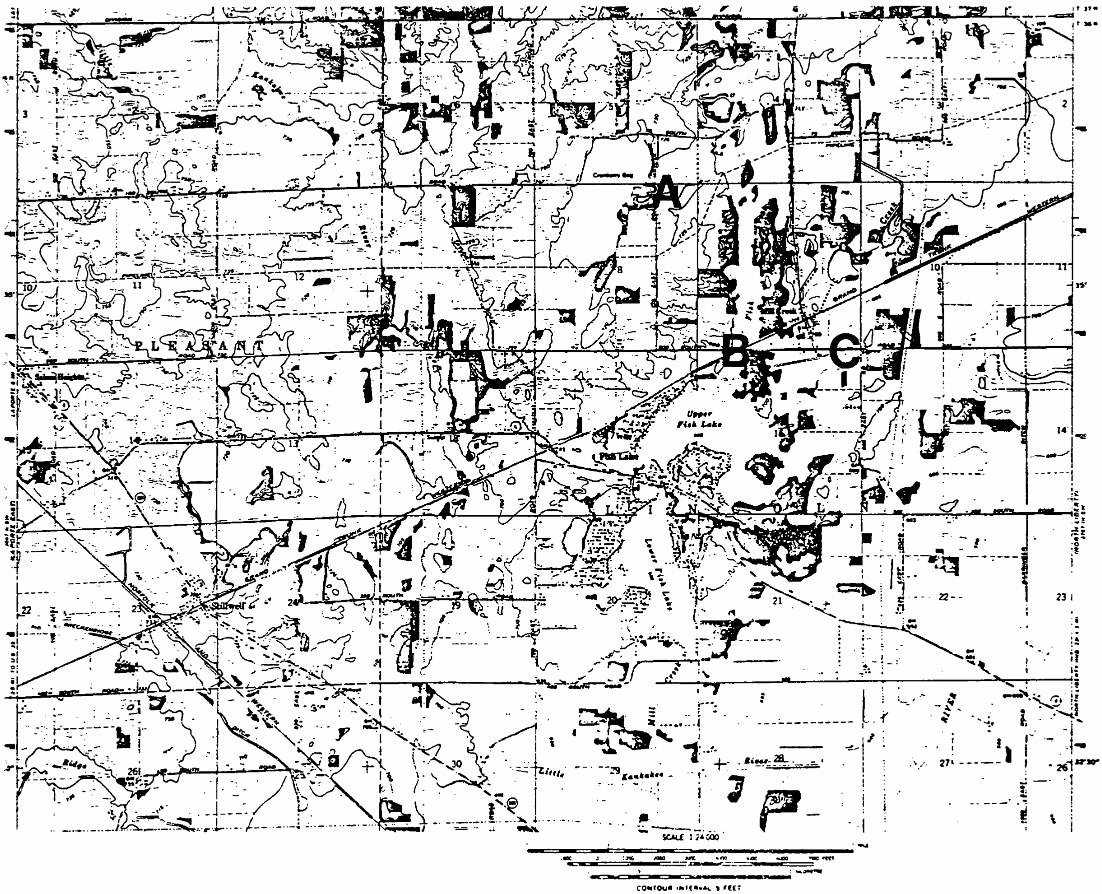
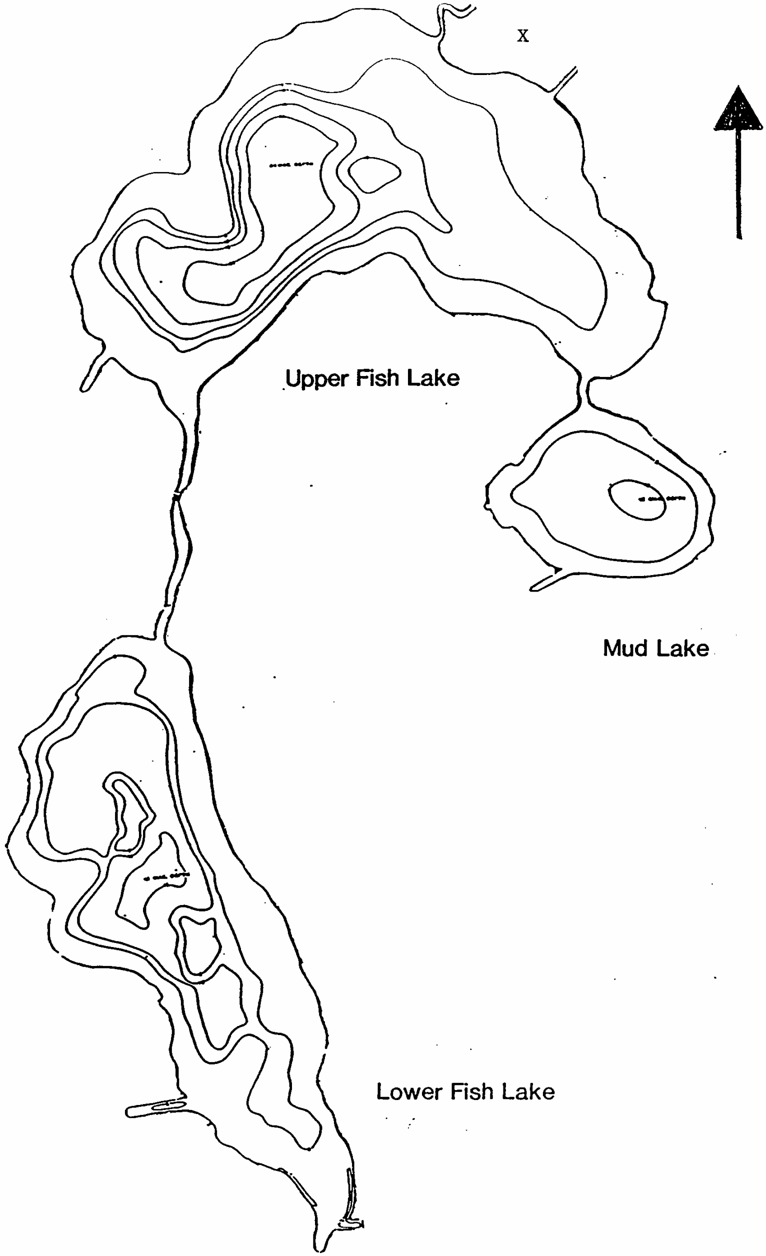


REGIONAL MAP OF STUDY AREA



MAP OF IMMEDIATE STUDY AREA SHOWING STREAM SAMPLING STATIONS. STREAM STATIONS ARE: (A) FISH CREEK AT PEAT BOG, (B) FISH CREEK AT COUNTY ROAD 200 S, AND (C) MILL CREEK AT COUNTY ROAD 200 S.



MAP OF FISH LAKE SYSTEM

FORWARD

Turnbell Engineering Co. of Fort Wayne, Indiana was responsible for all collection of limnological data for 1988. The author was responsible for completion of a final lake enhancement report based on these data as well as any historical data available in the files of federal, state, and local agencies and universities. The author was not responsible for any aspect of the study design for Turnbell Engineering.

EXECUTIVE SUMMARY

The Fish Lake system, LaPorte County, consists of three interconnected basins (Upper Fish Lake, Mud Lake, Lower Fish Lake). As early as 1969, aquatic macrophyte growth was considered excessive enough to warrant implementation of a control program to improve the fishery. Macrophyte problems continue today in spite of a major management effort by local residents. The greatest change in water quality occurred abruptly after 1975 as gizzard shad populations increased markedly and mid summer deoxygenation of the lower water column became common. Water quality generally increases southward through the Fish Lake system.

A majority of residential development occurred prior to the reduction of water quality in the mid 1970's and thus can be discounted as a principal contributing factor. As evidenced by delta formation at their mouths, the two principal streams of the Fish Lake system are delivering a great deal of sediment to the lake along with a high nutrient load. In addition to agriculture, a peat mining operation is currently active in a drained wetland of the Fish Creek watershed.

It is suggested that in-lake management techniques will not be extremely effective until watershed erosion and nutrient release are reduced substantially. It is recommended that the impact of the peat mining operation be investigated wetlands constructed in the course of both inlet streams to trap sediments and nutrients. The watershed is in need of implementation of structural and cultural land treatment practices. In-lake management practices should concentrate on control measures for excessive macrophytes and nutrient recycling from bottom sediments.

FISH LAKE

Introduction

Fish Lake, LaPorte County, is composed of two basins, Upper Fish Lake and Lower Fish Lake, that are connected by a channel slightly in excess of 0.25 miles in length (figure page x). Upper Fish Lake has a surface area of 139 acres and maximum and mean depth of 24 feet and 7.5 feet, respectively. A sub-basin at the southeastern corner of the lake is known locally as Mud Lake. The 1975 Indiana Eutrophication Index value was calculated as 22, placing the lake in the category of intermediate water quality (Class II). Surface area, maximum depth, and mean depth for Lower Fish Lake are 134 acres, 16 feet, and 6.5 feet, respectively. This lake displayed a Eutrophication Index value of 8 in 1975, thus assigning it to the category of best water quality (Class I). Legal lake level for both Upper and Lower Fish Lake is 688.22 feet and is controlled by a concrete spillway at the outlet into Mill Creek. Lower Fish Lake has no permanent inlets, while Upper Fish Lake has two that drain a predominantly agricultural watershed. Fish Creek enters from the north and drains a section of the watershed, which in addition to agriculture, has undergone extensive draining of bogs for peat mining. Mill Creek also enters Upper Fish Lake along the north shore, is channelized along most of its length, and drains a predominantly agricultural section of the watershed.

The present study was initiated because of lake residents' concerns regarding excessive submergent weed growth, a reduced quality recreational fishery, and observation of siltation in Upper Fish Lake associated with delivery of erosion products from the watershed especially during early spring rains.

This report is designed to define the current water quality of Upper and Lower Fish Lakes and to determine whether current values represent a marked decline in water quality within the historical past. Accordingly, it has been separated into three subsections. The first section presents a detailed examination of the historical database on the water quality for the Fish Lake system. The second section summarizes the water quality analyses conducted as part of the 1988 investigation by Turnbell Engineering and compares values to earlier studies. Management implications from the analysis of past and current water quality constitute the third section of the report.

Historical Water Quality

Database

A total of 12 separate studies were conducted on the Fish Lake system between 1955 and 1988 for which data were available (Table 1). The United States Geological Survey constructed a bathymetric map for Upper Fish Lake in 1955 and Lower Fish Lake in 1956, but collection of water quality data on the lake did not begin until 1969. The Indiana Department of Natural Resources surveyed the fish community 8 times after 1967 and in several of these surveys included data on water chemistry and macrophytes. The Indiana State Board of Health visited the lake once in the mid-1970's to collect water chemistry and biological data for construction of a eutrophication index for classifying the lake relative to other lakes in the state. No records on bacterial sampling in the lake system could be found in the files of the LaPorte County Health Department, and no other data were found in the files of state and federal agencies or as research projects conducted by universities of the state.

Physical/Chemical Parameters

A total of ten physical and chemical parameters have been measured at Fish Lake at a frequent enough intervals to be useful in delineating historical trends (Table 2). Secchi depth transparency is a good estimator of either inorganic turbidity from suspended sediment or algal biomass. As Secchi values have historically been recorded during summer, it is likely that they reflect algal biomass rather than suspended inorganic sediment. It is expected that Secchi values should get progressively lower throughout summer as algal biomass builds in response to steadily increasing temperature. Thus, it is only valid to make interyear comparisons for individual months. With the exception of August 1975, all previous Secchi readings were made during June (Table 2, Figure 1). Secchi values for June were greatest during 1969 with 1974 and 1975 displaying a progressive decline in values. Values since the latter date have oscillated somewhat but have never reached the maximum values recorded during 1969 and 1974. Secchi readings were made in 1988 only during August and were lower (6.6 feet Mud Lake, 4.9 feet Upper Fish Lake, 5.9 feet Lower Fish Lake) than the 6.7 feet from August 1975. Secchi data suggest that there has been a progressive decline in water quality since at least the early 1970's with the greatest change occurring between 1969 and 1975.

As with Secchi disc transparency, mean water column dissolved oxygen values are expected to decrease throughout the summer in response to increasing temperature and algal

Table 1. Chronology of Investigations at Fish Lake

1955	United States Geological Survey. Construction of bathymetric map for Upper Fish Lake.
1956	United States Geological Survey. Construction of bathymetric map for Lower Fish Lake.
1967	Indiana Department of Natural Resources. Survey of fish community.
1969	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1973	Indiana Department of Natural Resources. Survey of fish community.
1973	Indiana Department of Natural Resources. Selective fish eradication with antimycin and stocking with 15,000 largemouth bass fingerlings (3-6 inches) and 2,000 six-inch channel catfish.
1974	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1975	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1975	Indiana State Board of Health. Survey of several physical/chemical parameters and algal abundance and composition for construction of BonHomme eutrophication index for Upper and Lower Fish Lakes.
1976	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1978	Indiana Department of Natural Resources. Survey of fish community and physical/chemical parameters.
1984	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.

Table 2. Historical Changes in Physical and Chemical Parameters at Fish Lake for the Period 1969-1988.

Historical Data		6/69	6/74	6/75	8/75	6/76	6/78	6/84	5/88	8/88
Secchi	feet	11	9	3.6	6.7	6.3	7.6	4		5.8
Mean Dissolved Oxygen	mg/L	6.64	7.4	6.8	6.15	4.8	4.7	2.7	9.3	4.2
Alkalinity	mg/L as CaCO3	161.5	176	240		172.5	183.5	187	160	
pH		7.75	8	8		8.25	8.5	8.5	6.9	
Conductivity	umhos/cm								330	392
Ca	mg/L									
Fe	mg/L	0.2								
K	mg/L	1								
Mg	mg/L									
Mn	mg/L	0.02								
Na	mg/L	4								
Cl	mg/L									
SO4	mg/L	19								
Total Phosphorus	mg/L	0.6		0.35	0.025				0.03	0.03
Ortho Phosphorus	mg/L				0.015				0.03	0.03
Nitrate-N	mg/L				0.1				0.25	0.01
Ammonia-Nitrogen	mg/L				0.2				0.22	0.23
Total Kjeldahl N	mg/L				0.8				0.91	0.55
Nitrite-Nitrate	mg/L			0.9					0.02	0.01
Chlorophyll	mg/m3									0.021

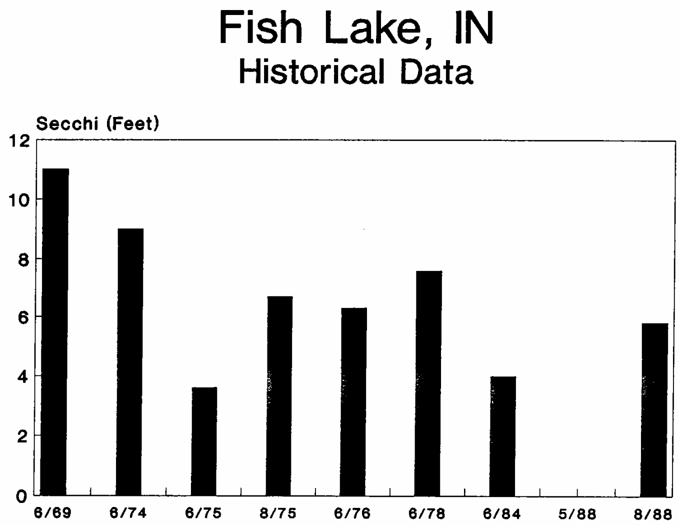


Figure 1. Historical Changes in Secchi Transparency for the Period 1969-1988.

production (Table 2). Since June 1976, early summer mean oxygen values in the water column of Fish Lake historically remained below 5.0 mg/L suggesting fairly eutrophic conditions. Mean water column values during June for the period 1969-1975 remained greater than 6.5 mg/L, while comparable readings for 1976-1984 were consistently less than 5.0 mg/L. Additionally, comparison of mean values for August 1975 (6.7 mg/L) and August 1988 (4.2 mg/L) is further evidence for a progressive reduction in mean oxygen values for the water column of Fish Lake since at least 1969. As noted for Secchi disc transparency, these data suggest a progressive decline in water quality with the greatest change occurring prior to 1975.

A good measure of the degree of eutrophication is provided by the extent of water column anoxia in mid summer (Table 3). The water column of Fish Lake was completely oxygenated during June in the period 1969-1975, but has displayed anoxic conditions below a depth of 15 feet since then. Comparison of historical data for August suggested that while anoxia was not noted in the water column of Lower Fish Lake during 1975, it was apparent below a depth of 9.8 feet in 1988. The depth to anoxia was similar between 1975 and 1988 in Upper Fish Lake, 10 feet and 13 feet, respectively. Although historical data were not available, Mud Lake in August 1988 displayed the shallowest depth to initiation of anoxia (8.1 feet).

Alkalinity, a measure of the carbonate buffering capacity of lakes, increased progressively during the period 1969-1975 after which it declined and has remained relatively steady to 1988 (Table 2, Figure 2). As will be discussed later, alkalinity can be a useful parameter for assessing changes in watershed delivery of erosion products through human activities. Taken alone, the data suggest an alteration in watershed management practices during the early to mid 1970's that resulted in increased delivery of carbonate rich material to Fish Lake.

Although the remaining physical and chemical parameters were sampled too infrequently to provide any historical perspective (Table 2), examination of the limited database for total phosphorus suggested a reduction in water column values between 1969 and 1975, with 1988 values being similar to August 1975 (Figure 3). It is likely that phosphorus loading to the lake has not decreased, rather nutrient uptake by the accelerated expansion of submergent macrophytes has proven effective at depleting water column phosphorus levels.

Table 3. Historical Records of Water Column Anoxia in Fish Lake, IN

Observation		Initial Depth of <1 mg/L Dissolved Oxygen
June:		
1969		No Anoxia
1974		No Anoxia
1975		No Anoxia
1976		15 feet
1978		15 feet
1984		15 feet
August:		
1975	Upper	10 feet
	Lower	No Anoxia

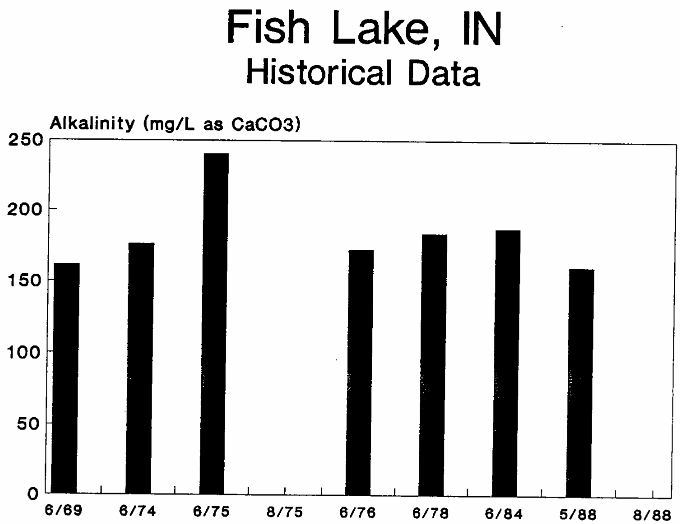


Figure 2. Historical Changes in Alkalinity for the Period 1969-1988.

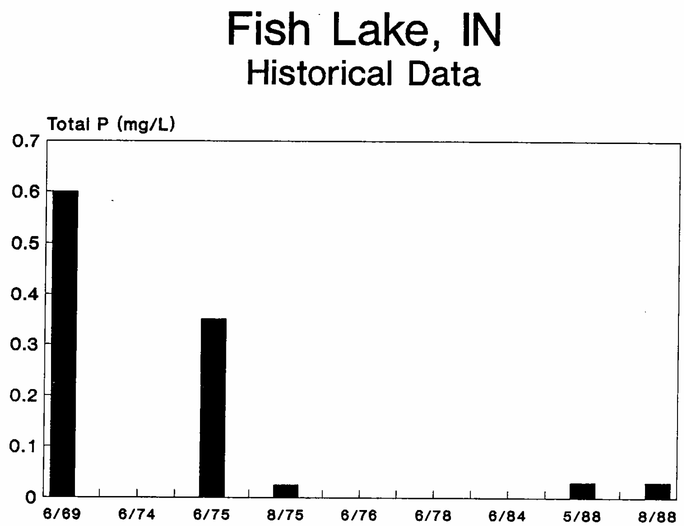


Figure 3. Historical Changes in Total Phosphorus for the Period 1969-1988.

Microbiology

Neither the LaPorte County Health Department nor the Indiana Department of Environmental Management had any historical microbiological data from the Fish Lake system.

Phytoplankton

Phytoplankton samples have been collected only once as part of the Indiana Department of Environmental Management survey in the summer of 1975. Representatives of four algal groups were identified in Upper Fish Lake (Table 4), but Oscillatoria, a blue-green alga characteristic of eutrophic lakes, dominated the phytoplankton assemblage. Total algal abundance in the upper water column (0-5 feet) was estimated at 2,800 units\mL. Although total phytoplankton abundance was similar (3,000 units\mL), the phytoplankton assemblage of Lower Fish Lake was markedly different from that of Upper Fish Lake (Table 5). Four algal groups were identified and the assemblage was dominated by Ceratium, a dinoflagellate. No previous investigation has mentioned problems with excessive algal blooms in the Fish Lake system.

Macrophytes

The macrophyte (aquatic weed) community was examined in 1969 and 1984 as part of Indiana Department of Natural Resources fish surveys (Table 6). The greatest taxonomic diversity recorded has always been for the submergent community. Approximately 50% of the surface area of Mud Lake was considered colonized by macrophytes in 1969 and the community was dominated by sago pondweed, which reached greatest abundance in 3-6 feet of water. Spatterdock formed a band 50-100 feet wide along the entire shore of the lake. Upper Fish Lake displayed macrophytes over 25% of its surface area with water milfoil and coontail forming dense growth along the north shore in 3-8 feet of water. Chara (1-5 feet), flatstem pondweed (4-8 feet) and sago pondweed (3-6 feet) were also abundant in the lake. It appeared that weed growth in Upper Fish was minimal in water greater than 8 feet deep.

The 1969 survey also noted that the channel separating Upper and Lower Fish Lakes was 80% colonized by macrophytes with eel grass covering most of the bottom and both flatstem pondweed and Chara considered abundant. Finally, macrophytes colonized approximately 20% of the surface area of Lower Fish with coontail (2-8 feet water depth), curly pondweed (2-8 feet), and Chara (1-5 feet) being the most abundant taxa.

The plant taxonomic composition appears to have changed little between 1969 and 1984 (Table 6). Although information

Table 4. Phytoplankton Composition of Upper Fish Lake
August 1975

Algal Group	Genus
Diatoms	Cyclotella
	Fragilaria
	Melosira
	Navicula
	Stephanodiscus
	Synedra
Greens	Chlorella
	Coelastrum
	Microspora
	Scenedesmus
	Ulothrix
Blue-Greens	Anabaena
	Anacystis
	Oscillatoria
Dinoflagellates	Ceratium
	Dinobryon
	Peridinium

Table 5. Phytoplankton Composition of Lower Fish Lake
August 1975

Algal Group	Genus
Diatoms	Melosira
	Microsiphona
Greens	Chlorella
Blue-Greens	Anabaena
	Anacystis
Dinoflagellates	Ceratium

Table 6. Species Composition of the Macrophyte Community of Fish Lake During 1969 and 1984.

Species	Common Name	1969 Mud	1969 Upper	1969 Lower	1969 Channel	1984 Fish
SUBMERGENTS:						
Ceratophyllum demersum	coontail	X	X	X	X	X
Chara spp.	chara		X	X	X	X
Elodea canadensis	elodea		X	X	X	X
Myriophyllum spp.	water milfoil	X	X		X	X
Najas flexilis	bushy pondweed		X		X	
Potomogeton crispus	curly pondweed		X	X	X	X
Potomogeton foliosus	leafy pondweed				X	
Potomogeton illinoensis	Illinois pondweed			X		
Potomogeton pectinatus	sago pondweed	X	X	X	X	X
Potomogeton pusillus	small pondweed		X	X		
Potomogeton zosteriformis	flatstem pondweed	X	X	X	X	
Utricularia sp.	bladderwort		X			
Vallisneria americana	eel grass		X	X	X	X
EMERGENTS:						
Dianthera americana	water willow	X	X	X		X
Sagittaria latifolia	arrowhead	X	X	X	X	X
Scirpus americanus	bulrush	X	X	X	X	X
Sparganium sp.	bur reed			X	X	
Typha latifolia	common cattail		X			X
FLOATING LEAVED:						
Nuphar advena	spatterdock	X	X	X	X	X
Nymphaea tuberosa	waterlily	X	X	X	X	X
FREE FLOATING:						
Lemna minor	duckweed				X	

for individual basins of the Fish Lake system was not provided in 1984, the dominant plants were listed as sago pondweed in 3-6 feet water depth and Chara, water milfoil and coontail in 4-8 feet of water.

As early as 1969, the DNR noted that the densities of both emergent and submergent aquatic weeds were sufficient to be considered a problem in the Fish Lake system. It was suggested that implementation of a weed control program would likely result in increased body size of game fish. Between 1969 and 1973, lake residents instituted such a weed control program, but the 1973 DNR report suggested that it should be expanded. The 1974 DNR report suggested that the weed control program in conjunction with a selective fish eradication program undertaken by DNR in 1973 had resulted in increased body size of recreationally important fish taxa. In spite of an increased expenditure by the Fish Lake Property Owners from $1,300 in 1974 to $6,000 in 1975 and continuance of an annual weed control program, all subsequent DNR reports indicated a need for a further expansion in the plant management effort. Even as late as 1978 and 1984, the lake was considered to be heavily weeded.

Fish

The Indiana Department of Natural Resources surveyed the fish community of Fish Lake eight times between 1967 and 1984. Data were found for all surveys except 1967. All surveys were based on both electrofishing and gill net collections, and the 1978 and 1984 surveys also included traps (Table 7). With the exception of 1973, gillnet sampling effort was roughly comparable in all surveys.

A listing of the individual species caught and the contribution of each to total fish abundance caught during DNR surveys from 1969-1984 is presented in Table 8. Although in excess of 26 taxa have been identified from Fish Lake, bluegill, largemouth bass, redear, and black crappie have been the major taxa numerically since 1969. Since at least 1978 (Table 9), gizzard shad clearly has been the dominant fish on a weight basis (25-34% of total fish weight) followed by northern pike (32% in 1984), and largemouth bass (8-17%). Other important taxa to total fish weight (1975-1984) include bluegill (6-13%), channel catfish (2-13%) and spotted gar (4-19%). The remaining fish taxa have not represented over 10% of total fish weight in the lake since at least 1975.

Bluegill has been the most abundant fish in Fish Lake since at least 1969, but both its growth rate and condition have oscillated during the period. Although 45% of the bluegill population in 1969 was considered catchable, both the condition and growth of this species was considered

Table 7. Historical DNR Fish Sampling in Fish Lake, IN.

1967	Report missing in files of DNR	
1969	Electrofishing:	1 hr day and 1 hr night
	Gillnets:	4 for 96 hrs = 384 hrs total effort
	Seining:	6 50-foot drags
1973	Electrofishing:	2 hrs night
	Gillnets:	2 for 24 hrs = 48 hrs total effort
1974	Electrofishing:	2 hrs night
	Gillnets:	4 for 72 hrs = 288 hrs total effort
1975	Electrofishing:	2 hrs night
	Gillnets:	4 for 96 hrs = 384 hrs total effort
1976	Electrofishing:	1 hr night
	Gillnets:	4 for 48 hrs = 192 hrs total effort
1978	Electrofishing:	1 hr day and 1 hr night
	Gillnets:	4 for 96 hrs = 384 hrs total effort
	Traps:	2 for 96 hrs = 192 hrs total effort
1984	Electrofishing:	1 hr day and 2 hrs night
	Gillnets:	4 for 72 hrs = 288 hrs total effort
	Traps:	4 for 72 hrs = 288 hrs total effort

Table 8. Percentage Importance of Fish Species to Total Abundance in Fish Lake 1969-1984.

% Total Fish Abundance	1969	1973	1974	1975	1976	1978	1984
American Eel				0.1			
Black Bullhead					5.4	0.5	1.6
Black Crappie	11.3	0.5	2.7	1.9	8	2.7	2.9
Bluegill	36.8	51	44.3	53.7	39.8	37.3	46.4
Bluntnose Minnow	0.4						
Brook Silversides	3.2	6.2	0.4	0.9	0.1		
Brown Bullhead	4.4	0.5		1.1	2.8	0.5	0.4
Carp	1.2	0.5	0.4	0.6			1.4
Channel Catfish	0.4			1.7	4	0.5	2.2
Gizzard Shad		2.9	0.9	0.4	6.3	12	5.5
Golden Shiner	5.2	0.5	1.3	1.1	2	1.8	1.6
Grass Pickeral					0.5		
Green Sunfish				0.1			
Hybrid Sunfish		0.5		0.1			
Lake Chubsucker	2		0.9	0.4	0.8	2	1.2
Largemouth Bass	9.7	10	14.7	10.1	10.5	21	12.8
Longnose Gar	3.2		0.9	0.7	1.5	0.5	
Northern Pike		0.5		0.9			4.5
Pumpkinseed	4.2	1.7	1.9	4.6	2.5	2	2.9
Redear	3.6	11.5	9.3	9	11.8	7	5.5
Rock Bass				0.4			
Spotted Gar	4.4	3.2	2.3	2.4	3.8	0.5	1
Warmouth	2.8	1.7	8.5	3.6	3.5	4.1	1.4
White Crappie		0.5				0.5	0.4
White Sucker		0.5	1.3	0.3			0.2
Yellow Bullhead		1.2	0.9	1.4	0.3	0.5	
Yellow Perch	6.8	6.2	9.7	4.3	2.3	6.1	8.2

Table 9. Importance of Individual Fish Species Expressed as a Percent of Total Fish Weight for DNR Surveys at Fish Lake.

% Weight	1975	1976	1978	1984
American Eel	0.1			
Black Bullhead			0.5	2.3
Black Crappie	0.8	6.5	7.3	1.4
Bluegill	13.9	10.1	8.6	6.0
Brook Silversides	0.1			
Brown Bullhead	1.9	5.4	1.7	0.8
Carp	7.4			3.7
Channel Catfish	2.7	13.8	6.6	8.2
Gizzard Shad	2.3	5.6	34.6	25.0
Golden Shiner	0.6	1.8	1.0	0.3
Grass Pickeral		0.6		
Green Sunfish	0.1			
Hybrid Sunfish	0.1			
Lake Chubsucker	0.4	0.2	2.1	0.6
Largemouth Bass	8.9	12.0	17.6	8.9
Longnose Gar	9.8	17.1	3.3	
Northern Pike	26.5			32.0
Pumpkinseed	0.8	0.5	0.5	0.3
Redear	4.1	4.4	6.3	3.2
Rock Bass	0.3			
Spotted Gar	14.2	19.4	4.4	4.3
Warmouth	1.1	2.0	1.7	0.2
White Crappie			0.5	0.1
White Sucker	1.2			1.0
Yellow Bullhead	1.4	0.2	0.5	
Yellow Perch	1.5	0.7	3.4	1.7

below average for lakes of northern Indiana. Similarly, 33% of the largemouth bass was considered catchable, but condition was deemed below average. Only the black crappie was considered average-above average for both condition and growth. The 1969 survey concluded that Fish Lake had stunted fish populations for both bluegill and largemouth due to excessive growth of submergent aquatic weeds. In addition to implementation of an aquatic weed control program, DNR also suggested modification of the outlet control structure to prohibit upstream migration of undesirable fish taxa into the lake.

The bluegill population continued to be abundant but stunted during 1973 with only 27% of individuals considered catchable. Overall, the population was considered to be in worse condition than observed in 1969. Particular note was made of the fact that 1973 marked the first year that the rough fish gizzard shad was collected in the Fish Lake system. The DNR continued to recommend modification of the outlet to keep out rough fish such as gizzard shad, following which a selective fish eradication program and subsequent stocking with largemouth bass was needed to improve the fishery.

A selective fish eradication using antimycin was conducted during fall 1973 during which approximately 52.8 lbs. of fish/acre were removed. After the treatment, 15,000 largemouth bass fingerlings 3-5 inches long and 2,000 channel catfish fingerlings approximately 6 inches long were stocked. A 1974 follow-up survey noted a marked increase in the percent of the bluegill population considered catchable (27% in 1973, 58% in 1974), a finding supported by observations of local fishermen. Overall, the percentage of total fish comprised of gamefish increased from 71% in 1969 to 89% in 1974. Finally, based on a limited tagging experiment, it was estimated that approximately 50% of all catchable sized gamefish in the lake are harvested annually by fishermen.

The percentage contribution of gamefish had declined to 74% by 1976 and was influenced by a progressive increase in gizzard shad since their first appearance in 1973. The lake supported an excellent crappie population, and northern pike stocked by the Fish Lake Conservation Club were reproducing. No details on the latter stocking could be found.

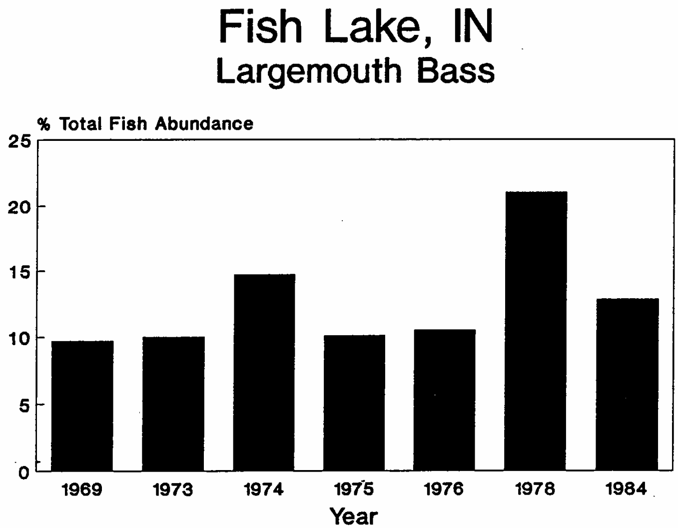
The gizzard shad population continued to expand so that by 1978 it was second in abundance and first in weight relative to the entire fish community. All shad caught in the 1978 survey were considered above the size range used as forage by largemouth bass, and it was suggested that the lake be stocked with northern pike to prey on the shad. It was further suggested that channel catfish be stocked to the lake.

Although details were not given, the 1984 DNR report noted that since 1980 the Fish Lake Conservation Club was engaged in an ambitious annual stocking program for largemouth bass, northern pike and channel catfish. Gizzard shad percentage abundance had declined markedly since 1978, but shad was still the second most important species on a weight basis. The relationship between the fish stockings and the shad decline was not evaluated. Fishing in the lake appeared to be better than previously, however, as Fish Lake supported one of the largest ice fish derbies in Indiana.

Changes in the percentage contribution of select species to total fish abundance and weight as recorded in the DNR surveys of 1969-1984 are summarized in Figures 4 and 5. Bluegill has remained the most numerous fish in Fish Lake since at least 1969. While its abundance contribution has remained relatively constant from 1969-1984, its contribution to total fish weight has declined progressively during the period. On the other hand, the relative abundance of largemouth bass did not change markedly, while the contribution to total fish biomass increased progressively between 1969 and 1978.

The most important fishery change in Fish Lake has been the notable increase in gizzard shad that took place since the mid 1970's. Shad were first encountered in DNR surveys in 1973 and contributed only slightly to total fish abundance through 1975. From 1975 through at least 1978, the relative abundance of gizzard shad increased progressively to over 12% of total fish abundance (Figure 4). Similarly, their contribution to total fish weight increased to 34% by 1978. Both relative abundance and weight of gizzard shad declined by 1984 and is at least partly associated with enhanced predation intensity resulting from northern pike stocking efforts.

Such high shad levels pose potential management problems in that once established, this species promotes phytoplankton dominance through its differential digestion of other algal taxa, elevated predation on large cladoceran zooplankton, and enhanced nutrient cycling for phytoplankton utilization (Crisman and Kennedy 1982, Crisman 1986, Crisman and Beaver 1988). Such a sharp increase in shad suggests that the eutrophication of Fish Lake increased markedly during the mid 1970's, a conclusion further supported by the development of pronounced summertime water column anoxia during the same period.



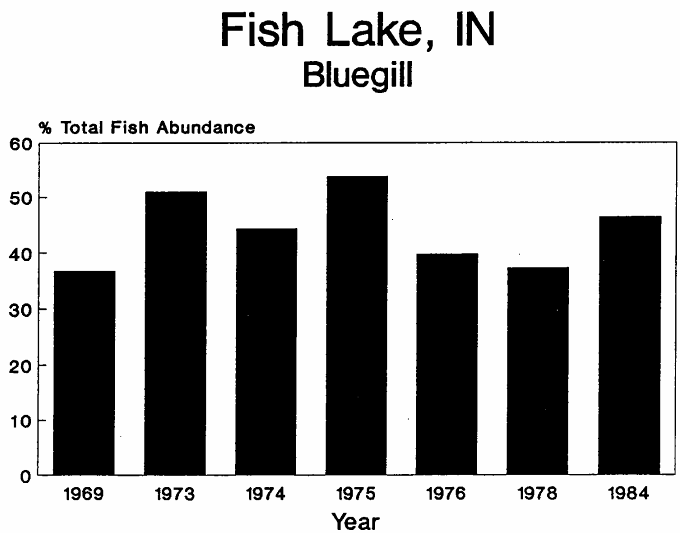
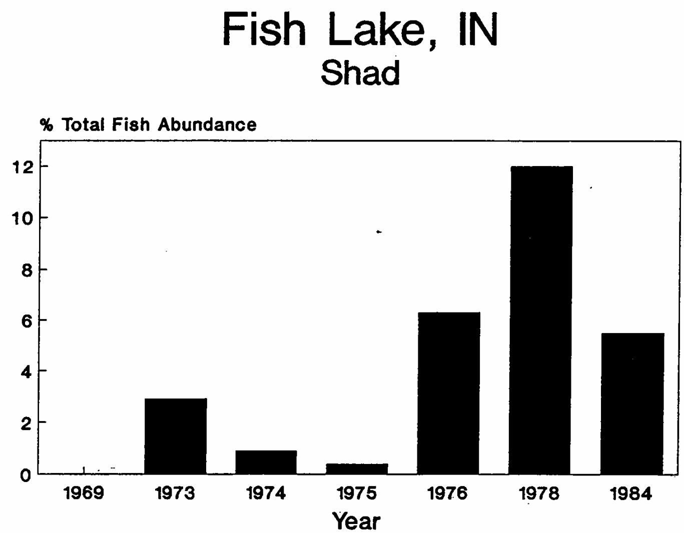


Figure 4. Changes in the Percentage Contribution of Select Species to Total Fish Abundance in Fish Lake for the Period 1969-1984.



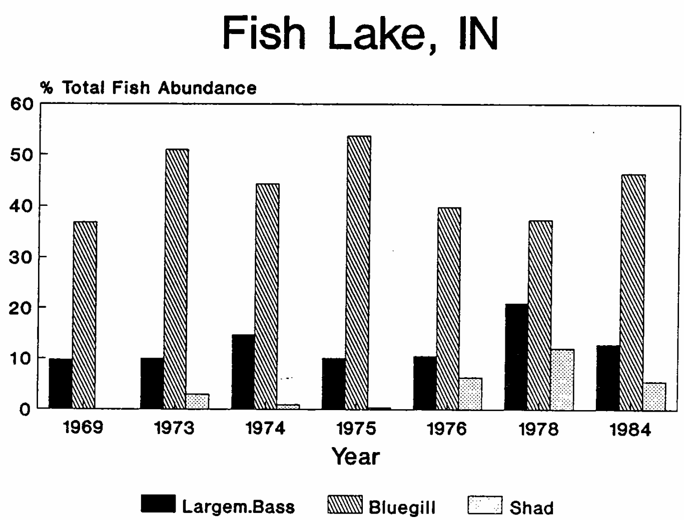
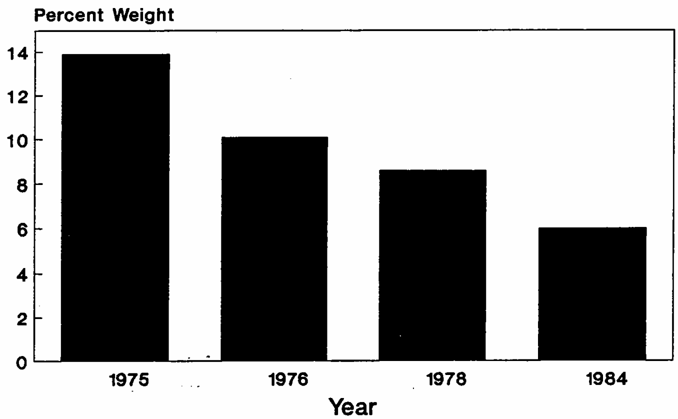


Figure 4. (Continued)

Fish Lake, IN
Bluegill



Fish Lake, IN
Largemouth Bass

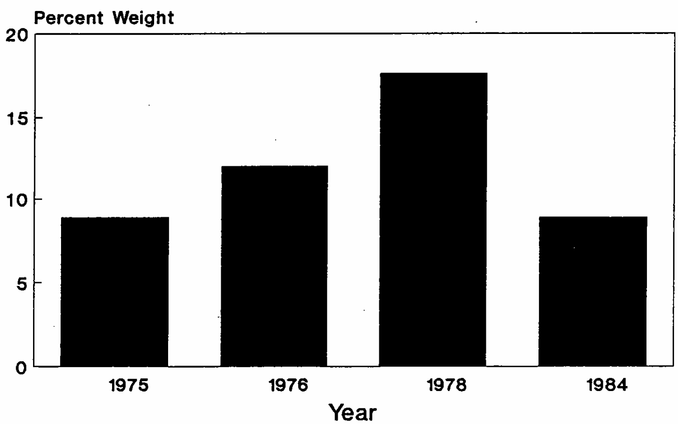


Figure 5. Changes in the Percentage Contribution of Select Species to Total Fish Weight in Fish Lake for the Period 1975-1984.

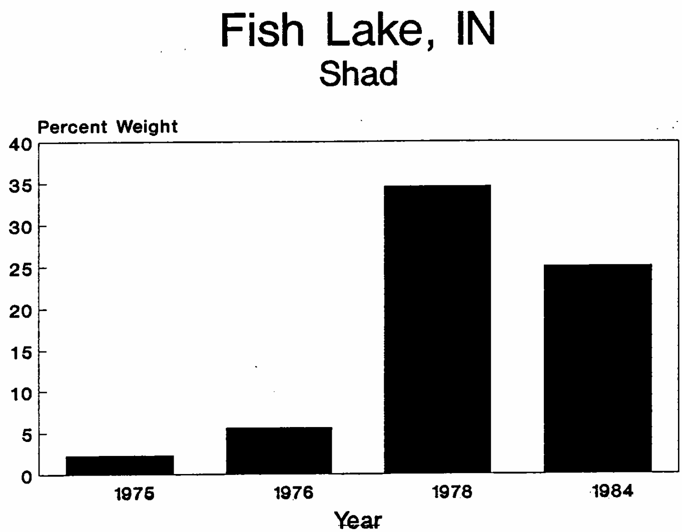


Figure 5. (Continued).

Current Water Quality

Methods

Water quality parameters were collected during 1988 on 23 May and 10 August. A single sampling station was established in Mud Lake (the eastern basin of Upper Fish Lake), Upper Fish Lake, and Lower Fish Lake near the point of maximum water depth in each (Figure 6). Dissolved oxygen and temperature profiles were determined with a YSI oxygen meter, and light transmission was estimated with a Secchi disc.

Water samples for chemical, bacteriological and chlorophyll analyses were taken from composite samples of the water column. After determining the depth of the thermocline using a YSI temperature-oxygen meter, a Kemmerer bottle was used to collect water from equal portions of the epilimnion, metalimnion, and hypolimnion. Conductivity, pH, and alkalinity were determined in the field on subsamples of this composite, and the remainder of the sample was iced for transport to the laboratory for determination of ammonia, total Kjeldahl nitrogen, nitrate, nitrite, total phosphorus, ortho phosphorus, suspended solids, chlorophyll, 5-day BOD, and bacteria counts. All analyses were performed according to Standard Methods (APHA 1985). Data for physical and chemical parameters for individual basins during the 1988 survey are presented in Table 10.

Phytoplankton samples were collected using a Wisconsin plankton net (80 um mesh). Two types of tows were made at each site: one from the five-foot depth to the surface, and a second from the top of the thermocline to the surface. Samples were preserved with Lugol's solution in the field and transported to the laboratory for analysis. Phytoplankton counts utilized Sedgewick-Rafter cell with taxonomy based on keys in Standard Methods.

Sediment contaminants were analyzed from surface sediments collected from the deepest section of Upper Fish Lake. A piston coring device equipped with a clear plexiglass tube was used to collect a one-meter core from the deepest section of Upper Fish Lake during July 1988. This technique permitted examination of the core to insure that the sediment-water interface was not disturbed during the coring operation. The upper 10 cm was retained for analysis and placed in a labelled plastic bag. This sediment was kept cool at 4^{o} C until analyzed. Prior to analysis, the sediment was thoroughly mixed. All analyses were performed by ATEC Environmental Consultants of Indianapolis.

Volatile compounds were analyzed on a Finnigan Incos 50 GC/MS/DS system utilizing SW 846 Method 8270 for Extractable

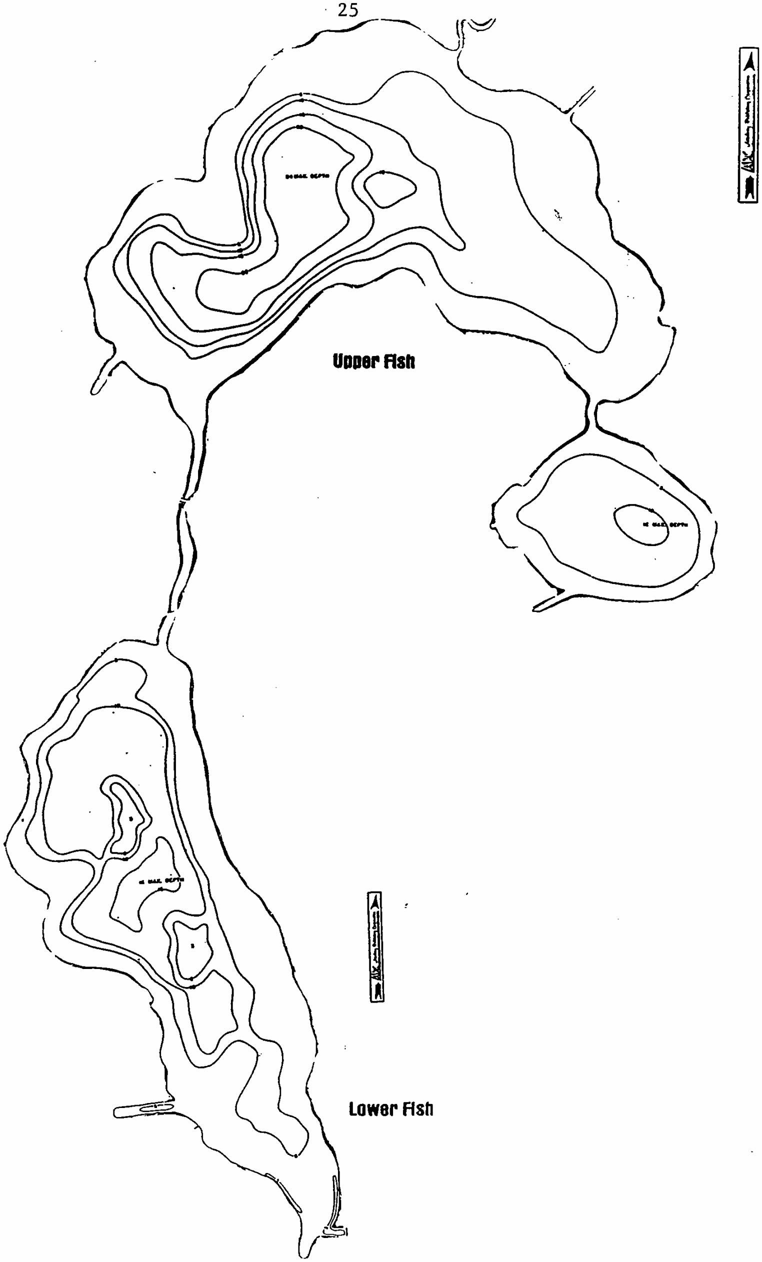


Figure 6. Bathymetric Map for Upper and Lower Fish Lakes.

Table 10. Physical/Chemical Parameters for Upper Fish Lake, Mud Lake and Lower Fish Lake During 1988.

Fish Lake	1988	May 23 Mud-L.	May 23 U-Fish	May 23 L-Fish	August 10 Mud-L.	August 10 U-Fish	August 10 L-Fish	5/23 Mean	8/10 Mean
Secchi	feet				6.6	4.9	5.9		
Mean Dissolved Oxygen	mg/L	8.7	9.6	9.525	4.5	3.3	4.8	9.3	4.2
Ammonia	mg/L	0.33	0.18	0.17	0.16	0.29	0.26	0.23	0.24
Total Kjeldahl N	mg/L	1.24	0.75	0.74	0.6	0.6	0.46	0.91	0.55
Nitrate	mg/L	0.14	0.4	0.21	0.01	0.01	0.02	0.25	0.01
Nitrite	mg/L	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01
Total Phosphorus	mg/L	0.05	0.02	0.03	0.04	0.04	0.02	0.03	0.03
Ortho Phosphorus	mg/L	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.03
N:P	atoms	76	149	83	42	49	82	103	58
Conductivity	umho/cm	296	348	346	382	424	371	330	392
Alkalinity	mg/L	140	180	160					
Chlorophyll	mg/L				0.004	0.02	0.038		
Temperature	C	20.8	20.7	21.25	27.9	23.1	28.1	20.9	26.4

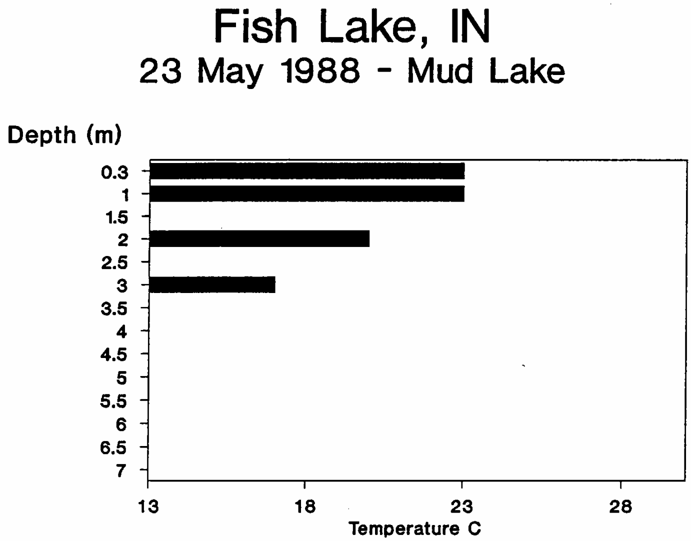
Organic Compounds. Prior to analysis, the system was tuned against Decafluorotriphenylphosphine and calibrated with the appropriate standard. PCB and pesticide analyses utilized a Varian 3400 Gas Chromatograph and Electron Capture Detection according to SW 846 Method 8080. Metals were analyzed on a Varian SpectrAA-10 Atomic Absorption Spectrophotometer according to the appropriate 7000 series method in SW 846.

Physical/Chemical Parameters

Temperature. The water columns of northern Indiana lakes greater than approximately five meters deep remain thermally stratified throughout most of the year. As a result of density-temperature relationships, complete mixing of the water column from top to bottom occurs only when water temperature reaches a uniform $4^{o}C$, the maximum density of water. This occurs twice a year in temperate lakes (spring and fall) associated with seasonal climatic changes. The length of the mixing period depends on the rapidity of climate change and can vary from a few days to less than a month. Lakes displaying two mixing periods per year are termed dimictic.

During the stratified period, the water column of Indiana lakes is divided into three zones based on temperature-density relationships. The uppermost well mixed zone is termed the epilimnion and extends from the surface to a depth roughly approximating the lower depth of wave action. The lowermost portion of the water column is the hypolimnion, a zone of density-isolated water that mixes with surface waters only during the short mixing periods. The portion of the water column that is transitional between the epilimnion and hypolimnion is termed the metalimnion. That one meter of the metalimnion displaying the greatest temperature change is called the thermocline.

Water column profiles clearly demonstrated that all three basins (Mud, Upper, Lower) were displaying thermal stratification by the end of May 1988 (Figure 7) with the thermocline being between two and four meters depth. The August pattern was markedly different (Figure 8) with only Upper Fish displaying any thermal stratification. Such a breakdown of stratification during mid summer is highly unusual in lakes of this depth in Indiana. Examination of the historical database from Fish Lake failed to demonstrate a similar pattern for any year between 1969 and 1984. The breakdown in stratification as well as the $2\text{-}3^{o}$ C greater than expected August water temperature during 1988 are likely a reflection of the extreme drought and temperature conditions of summer 1988 and should not be interpreted as normal values.



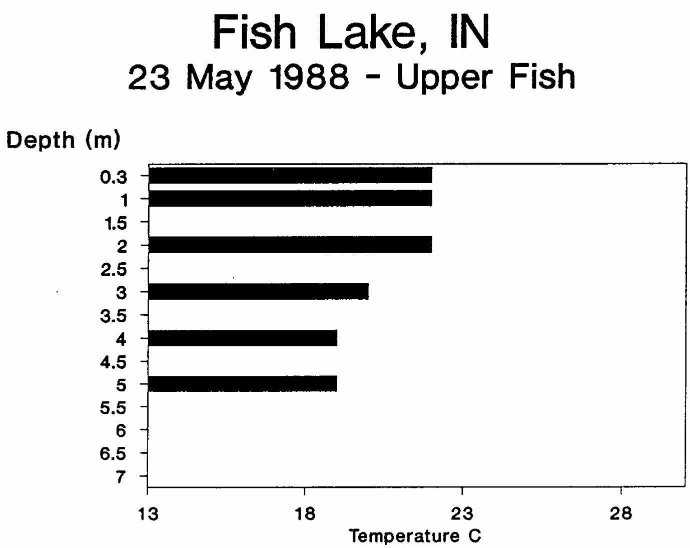


Figure 7. Temperature Profiles for the Fish Lake System During May 1988.

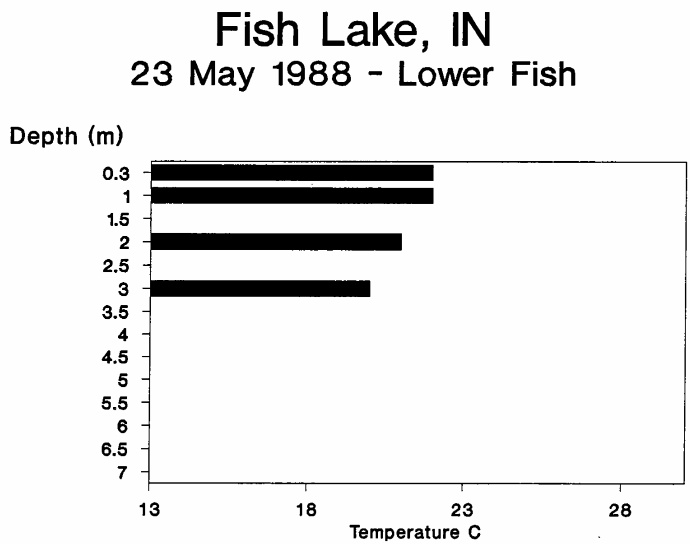
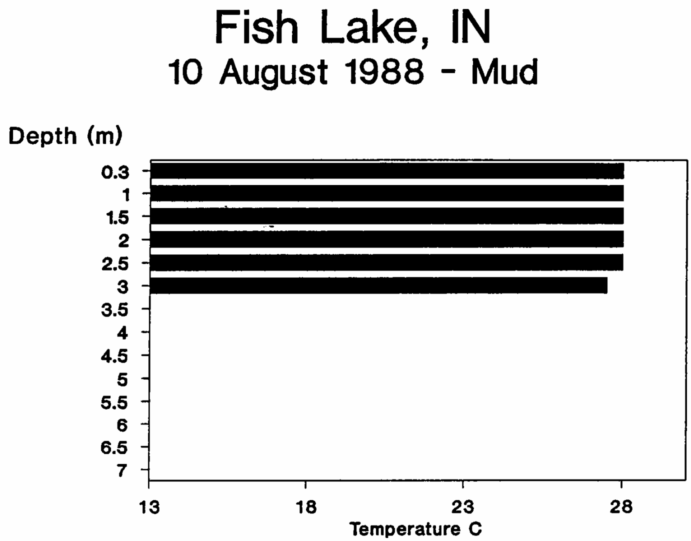


Figure 7. (Continued).



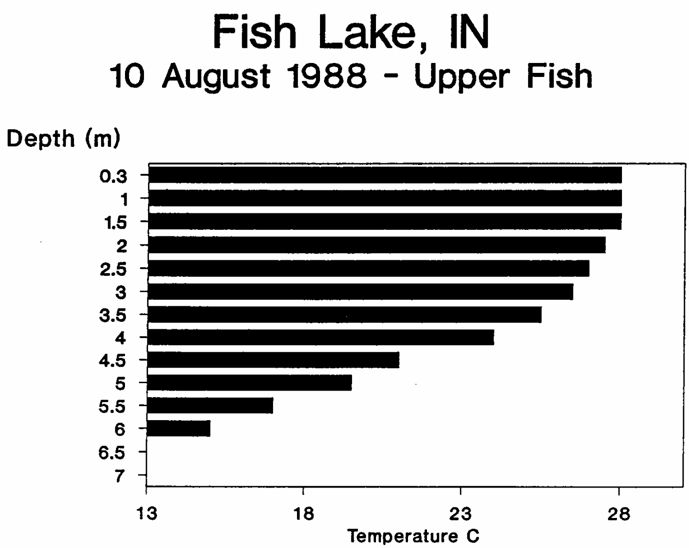


Figure 8. Temperature Profiles for the Fish Lake System During August 1988.

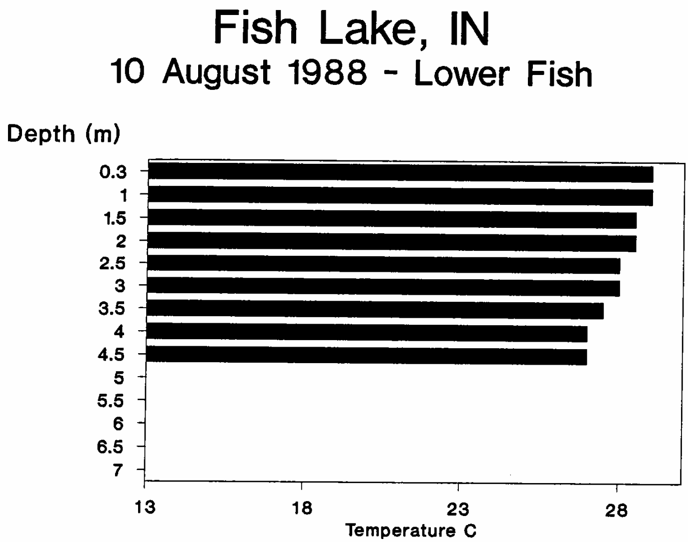


Figure 8. (Continued).

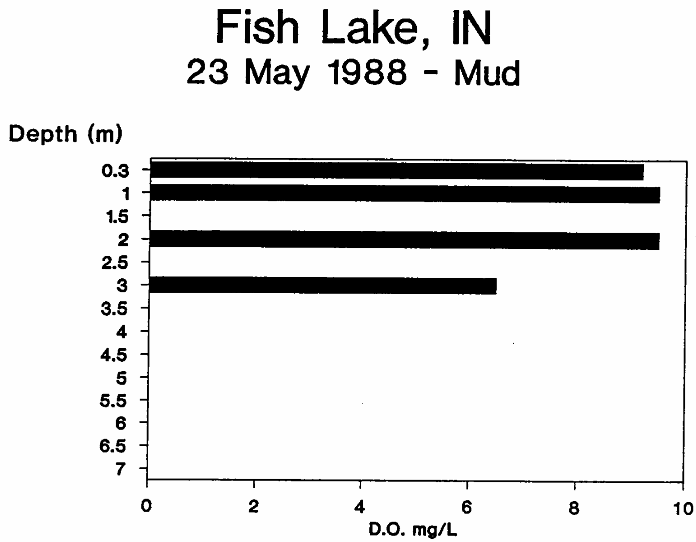
Dissolved Oxygen. Midsummer oxygen values in the lower portion of the water column of lakes is governed by the degree of thermal stratification and the overall trophic state of the lake. The higher the trophic state (eutrophication) the greater the amount of organic matter falling to the bottom of the lake to decompose. If the lake is deep enough to stratify, oxygen is not replenished in the bottom layers readily and is consumed during the decomposition process. Thus, the higher the trophic state, the greater the likelihood that the lake becomes anoxic in the bottom of the water column (hypolimnion).

The extent of deoxygenation of the lower portion of the water column (hypolimnion) at the three sampling stations of the Fish Lake system can not be evaluated for May 1988 because oxygen was measured only to a depth of three meters in the water column at each station (Figure 9). Only Mud Lake shown any reduction in oxygen content within the first three meters of the water column.

Pronounced water column deoxygenation was noted at all three sampling stations during August 1988 (Figure 10). As expected, the beginning of reduced oxygen corresponded to the bottom of the well mixed portion of the water column (epilimnion), the portion of the water column displaying the greatest temperature change per meter (thermocline). Mud Lake not only had the lowest oxygen values in the epilimnion, but also the shallowest depth to anoxia (2.5-3 m). The remaining two basins, Upper Fish and Lower Fish, reached anoxia at depths of 4.5 m and 3.5 m, respectively. All three basins displayed symptoms of severe eutrophication based on summertime oxygen profiles.

When expressed as a mean for the entire water column, dissolved oxygen during May was lowest in Mud Lake, with Upper and Lower Fish Lakes displaying nearly identical values. It must be remembered, however, that the May sampling regime did not assess oxygen below three meters at any of the three sites and thus is useless for evaluating the extent of water column anoxia for that month.

Oxygen concentrations were measured throughout the water column at all three sites in August 1988. While all three sites had mean oxygen values less than 5 mg/L, the most severe oxygen depletion was recorded in Upper Fish followed by Mud Lake and Lower Fish Lake (Figure 11). Progressive depletion of hypolimnetic oxygen concentrations throughout summer is a reflection of decomposition of phytoplankton settling out of the water column. Water column oxygen values undoubtedly decline sharply even in surface waters at nite in the three basins of the Fish Lake system when aquatic macrophytes and algae are no longer photosynthetic.



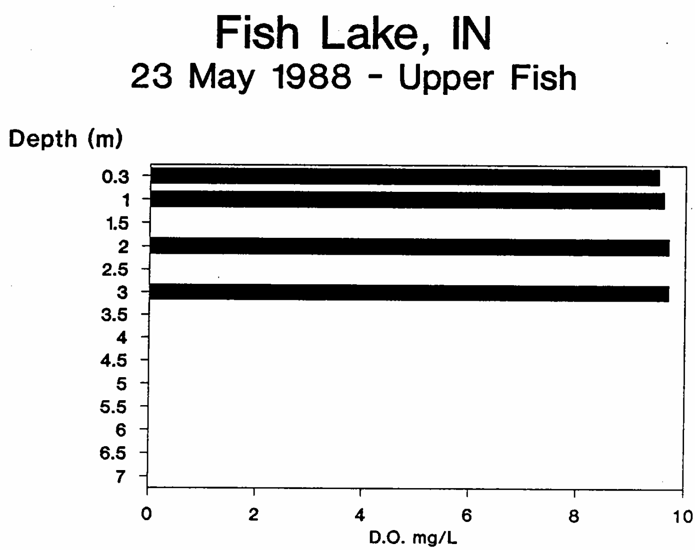


Figure 9. Dissolved Oxygen Profiles for the Fish Lake System During May 1988.

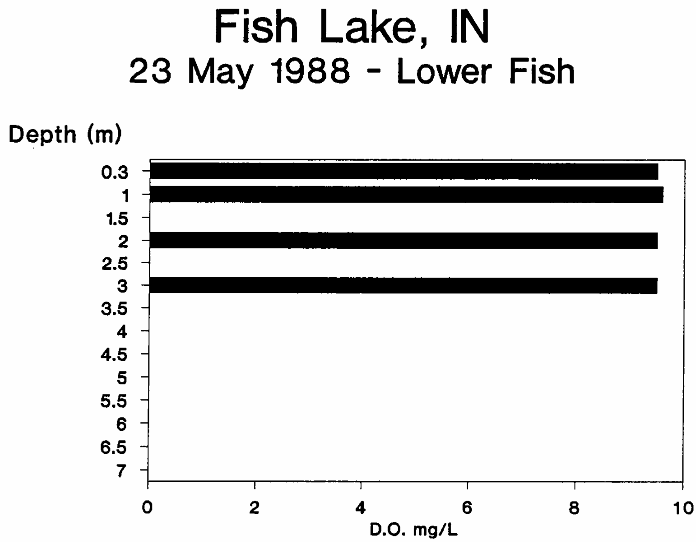
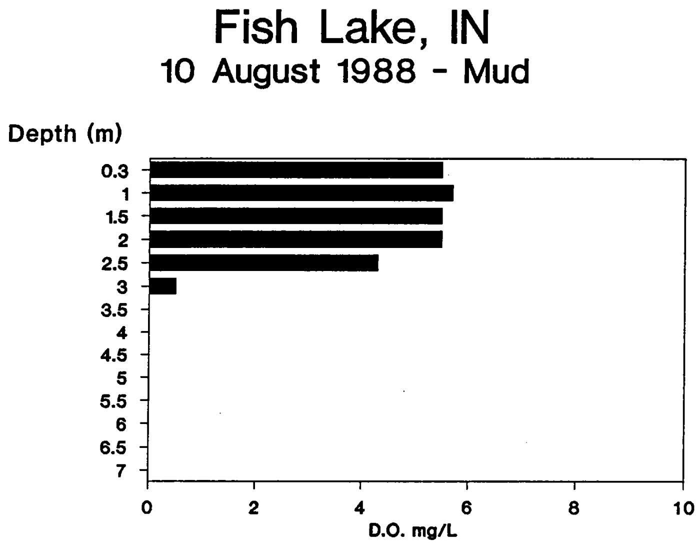


Figure 9. (Continued).



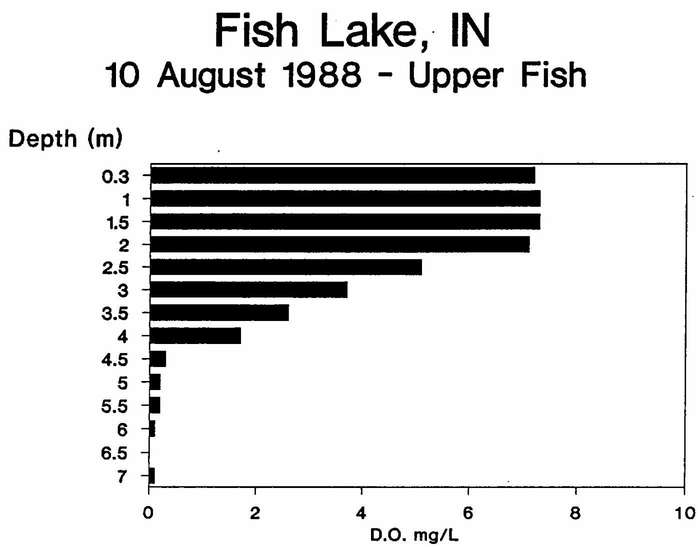


Figure 10. Dissolved Oxygen Profiles for the Fish Lake System During August 1988.

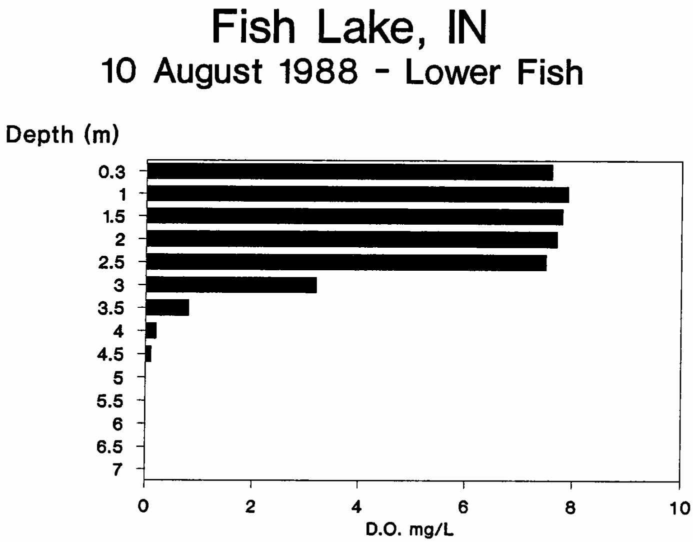


Figure 10. (Continued).

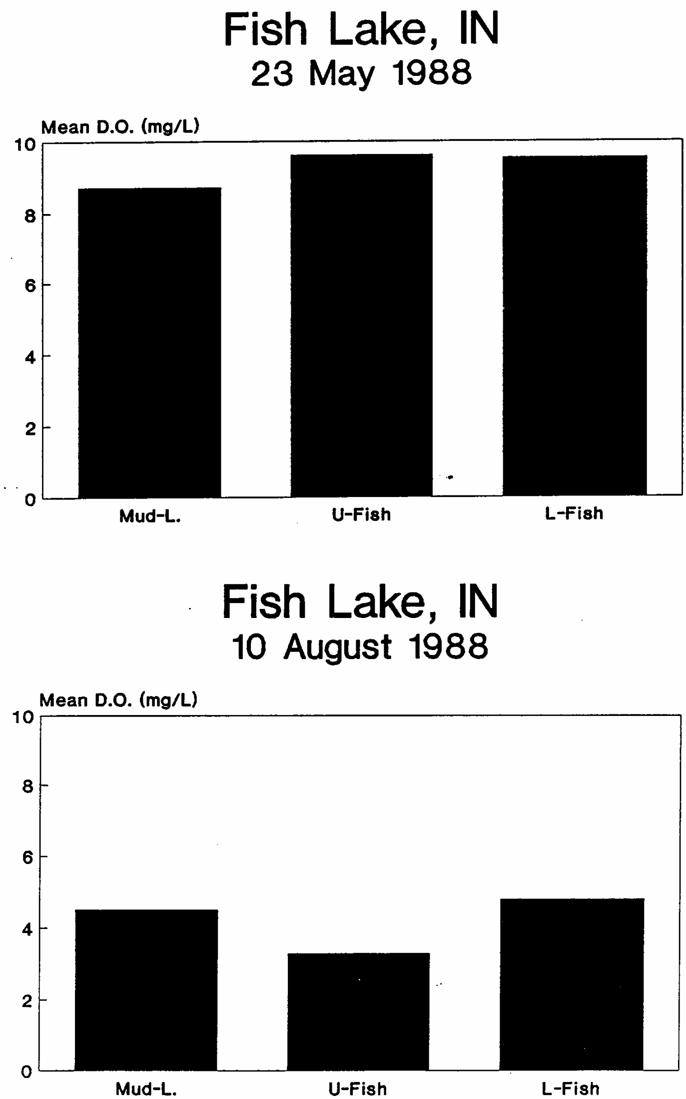


Figure 11. Mean Dissolved Oxygen for the Water Columns of Individual Basins of the Fish Lake System During 1988.

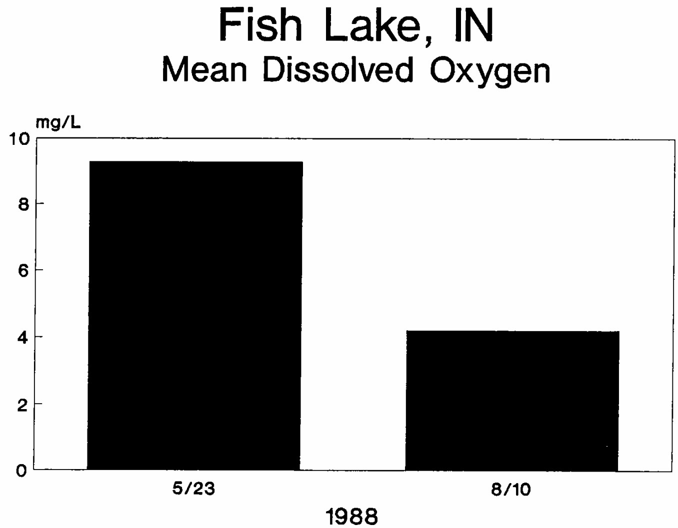


Figure 11. (Continued).

Historically, since 1976 Fish Lake has displayed severe deoxygenation of the water column below 15 feet (4.6 meters) depth as early as June (Table 3) with mean oxygen values for the water column at 2.7-4.8 mg/L (Table 2). During August 1975, mean water column oxygen value for Upper and Lower Fish Lakes were 5.2 and 7.1 mg/L, respectively, compared with comparable values of 3.3 and 5.9 mg/L during August 1988. The depth to anoxic conditions increased in Upper Fish between August 1975 (10 feet) and August 1988 (14.6 feet), but Lower Fish, which displayed no anoxia during 1975, was considered anoxic below 11 feet during August 1988. While it appears that midsummer oxygen depletion may have increased since 1975 in Lower Fish Lake, it is not known how much this is influenced by the extreme temperature and drought conditions of 1988.

Secchi Disc Transparency. As stated earlier in this report, the depth that a Secchi disc can no longer be seen in a water column is indicative of the amount of algae suspended in the water column to block light transmission. Thus, the shallower the Secchi depth during midsummer, the more productive (eutrophic) a lake is presumed to be. Secchi transparency was measured only once (10 August) during 1988 at the three sampling stations (Figure 12). Water was clearest in Mud Lake (6.6 feet) followed by Lower Fish Lake (5.9 feet) and Upper Fish Lake (4.9 feet). The only comparable historical data are for 7 August 1975, when Secchi values for Upper and Lower Fish Lakes were 7.5 feet and 5.9 feet, respectively. Thus, while clarity in Lower Fish was identical between 1975 and 1988, that of Upper Fish Lake was 35% lower in 1988. In general, Secchi transparency has been lower post 1975 than before (Figure 1).

Ammonia. The maximum ammonia concentration recorded during the 1988 survey was for Mud Lake during May (Figure 13). The remaining two basins during May, Upper and Lower Fish Lakes, were lower at 0.18 and 0.17 mg/L, respectively. Ammonia in Mud Lake dropped sharply during August to the lowest value reported in the 1988 survey, while ammonia increased in Upper and Lower Fish to 0.29 and 0.26 mg/L, respectively. Mean ammonia values for the Fish Lake system during May (0.22 mg/L) and August (0.23 mg/L) were comparable to the only historical data (0.2 mg/L in August 1975) for this parameter (Table 2).

Nitrite-Nitrate. Nitrite nitrogen concentrations were identical at all three sampling sites during both May and August 1988 with the former month being greater, 0.02 versus 0.01 mg/L (Figure 14). Nitrate values were an order of magnitude greater than nitrite in the three basins during May but were approximately equal to nitrite during August (Figure 15). Maximum nitrate concentrations were recorded in Upper Fish during May and Lower Fish during August. The 1988

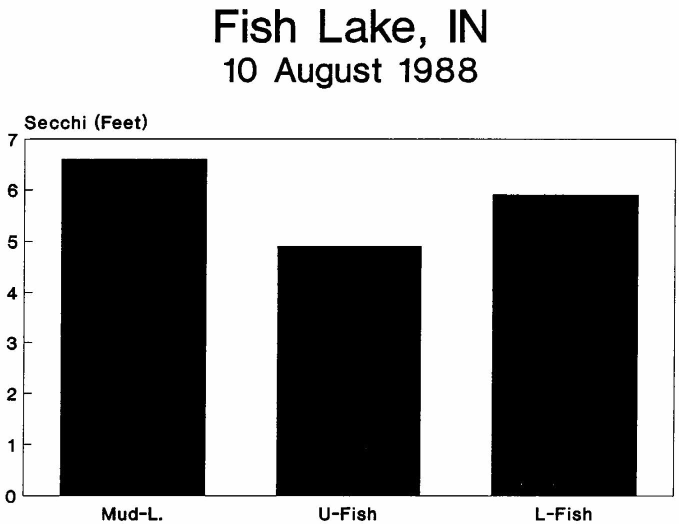
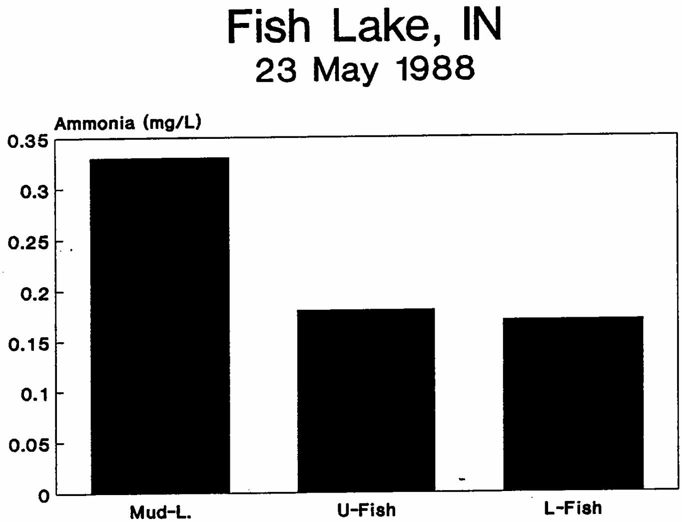


Figure 12. Secchi Disk in Individual Basins of Fish Lake During August 1988.



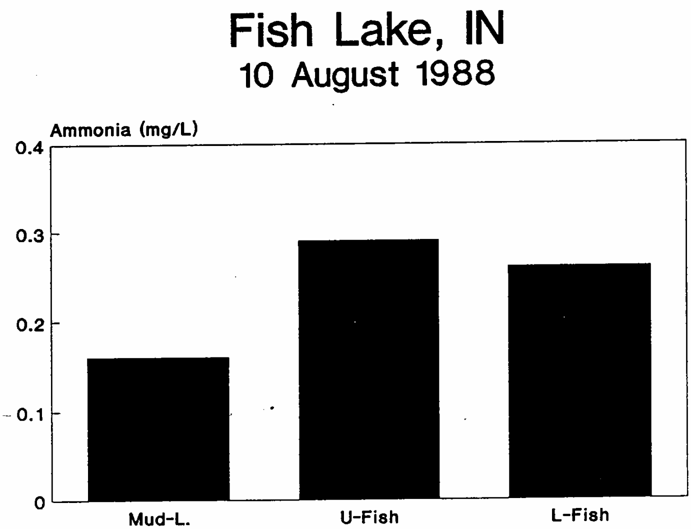


Figure 13. Ammonia Concentrations for Individual Basins of the Fish Lake System During May and August 1988.

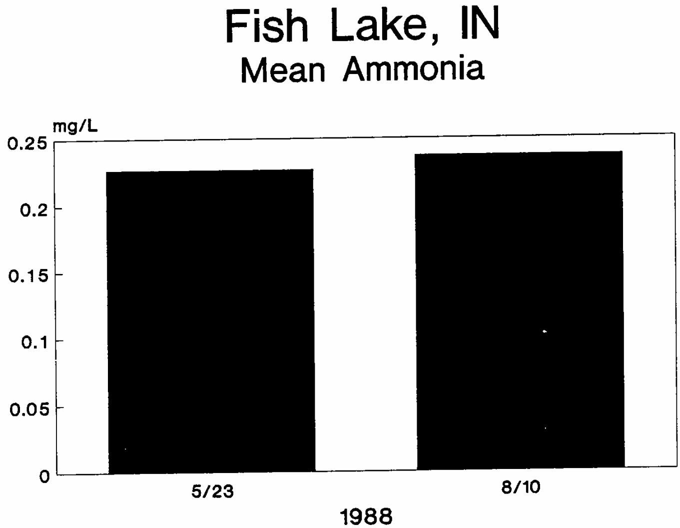


Figure 13. (Continued).

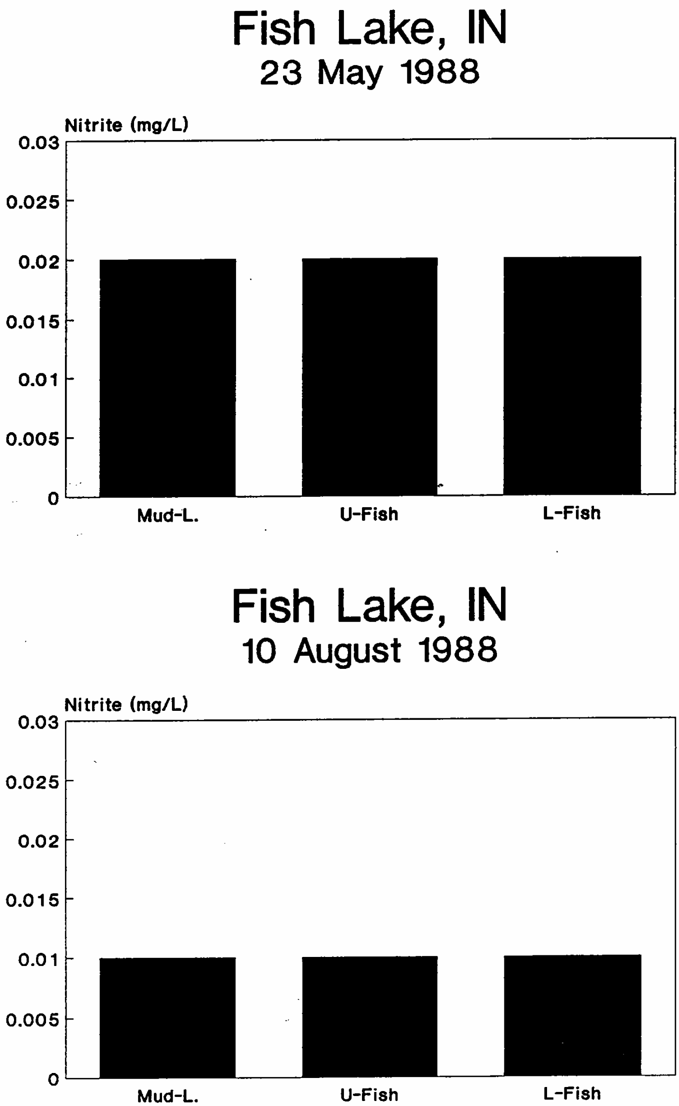


Figure 14. Nitrite Concentrations for Individual Basins of the Fish Lake System During May and August 1988.

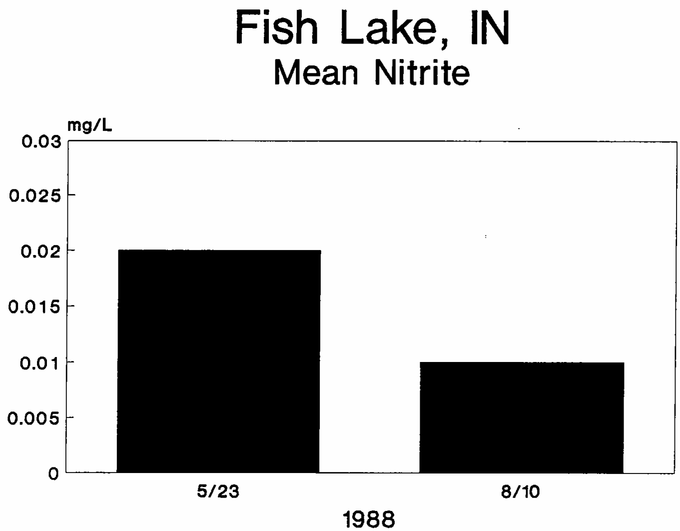
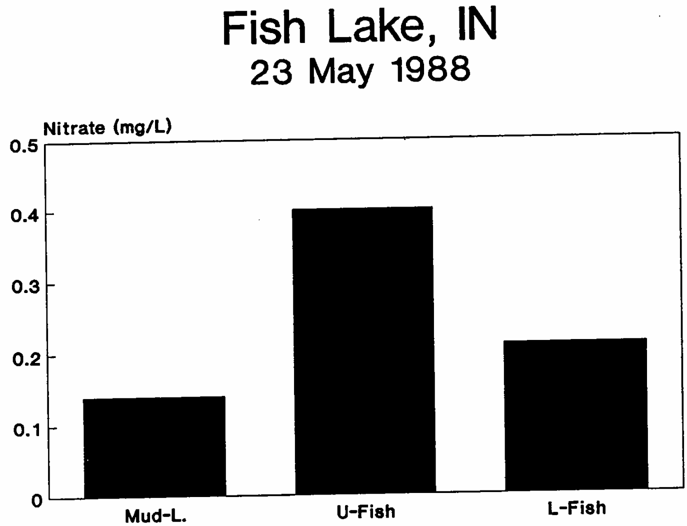


Figure 14. (Continued).



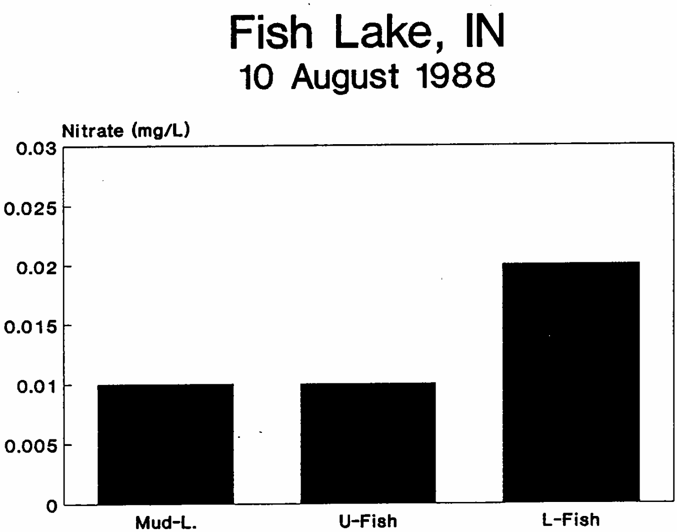


Figure 15. Nitrate Concentrations for Individual Basins of the Fish Lake System During May and August 1988.

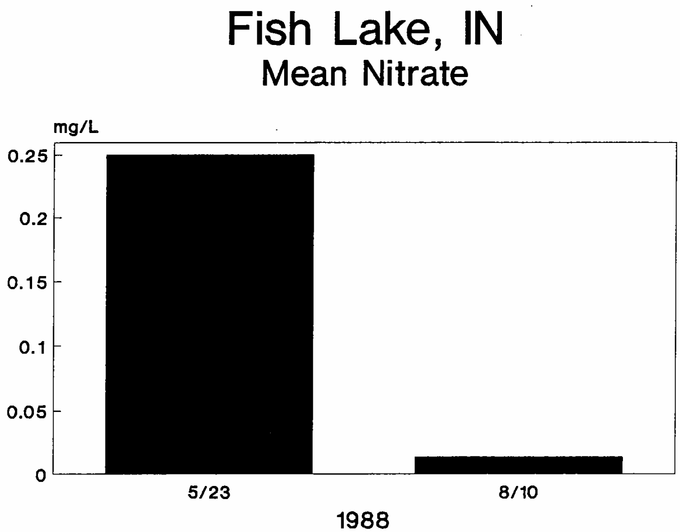


Figure 15. (Continued).

values for August approximated those of August 1975, the only other time that data were collected for this month (Table 2).

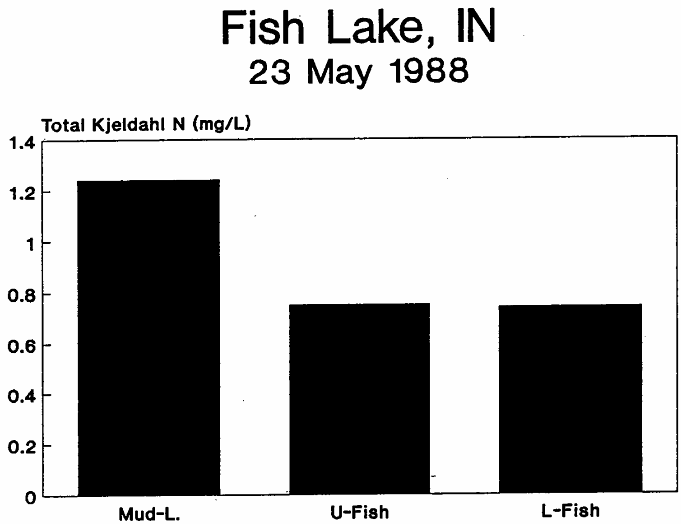
Kjeldahl Nitrogen. While May Kjeldahl nitrogen values were higher in all three basins than observed during August, Mud Lake displayed a concentration nearly double that found in either Upper or Lower Fish Lakes (Figure 16). Interbasin differences were greatly reduced by August with Lower Fish Lake having the lowest value of this parameter. All August 1988 values (range 0.46-0.6 mg/L) were only slightly lower than the only historical value (0.8 mg/L in 1975) for this month (Table 2).

Total Phosphorus. Mud Lake displayed the greatest total phosphorus of the three lake basins during May (Figure 17) with Lower Fish being second. Concentrations in both Mud and Lower Fish decreased by August, while Upper Fish increased. Total phosphorus values for both Upper (0.04 mg/L) and Lower (0.02 mg/L) Fish Lakes during August 1988 were similar to values (0.03 mg/L and 0.02 mg/L, respectively) recorded during August 1975 (Table 2).

Ortho Phosphorus. Ortho phosphorus concentrations were identical in all three basins during May 1988 (0.03 mg/L), but increased in Mud (0.04), decreased in Lower Fish (0.02) and remained unchanged (0.03) in Upper Fish during August (Figure 18). The mean ortho phosphorus value for the three basins combined was 0.03 mg/L during both May and August. All 1988 values were slightly higher than reported in August 1975 (0.015 mg/L), the only other time that ortho phosphorus has been measured (Table 2).

Nitrogen:Phosphorus Ratios. The ratio of total nitrogen to total phosphorus can be useful in delineating which of these two essential nutrients are limiting primary production in lakes. Numerous authors (Baker et al. 1981, Kratzer and Brezonik 1981, Canfield 1983) have proposed that N:P ratios less than 10 suggest nitrogen limitation, while those greater than 10 suggest phosphorus. The N:P ratios in all three basins of the Fish Lake system exceeded 70 during May suggesting that all were phosphorus limited (Figure 19). With the exception of Lower Fish, N:P ratios declined sharply in both Mud (42) and Upper Fish (49) during August suggesting that these basins were approaching nitrogen limitation as the summer progressed, and macrophytes and algae were actively utilizing the available phosphorus pool.

Conductivity. Conductivity was greatest in Upper Fish during both May (348 umho/cm) and August (424 umho/cm) 1988 (Figure 20). Values in all three basins increased between May and August. No historical data for this parameter were available for comparison.



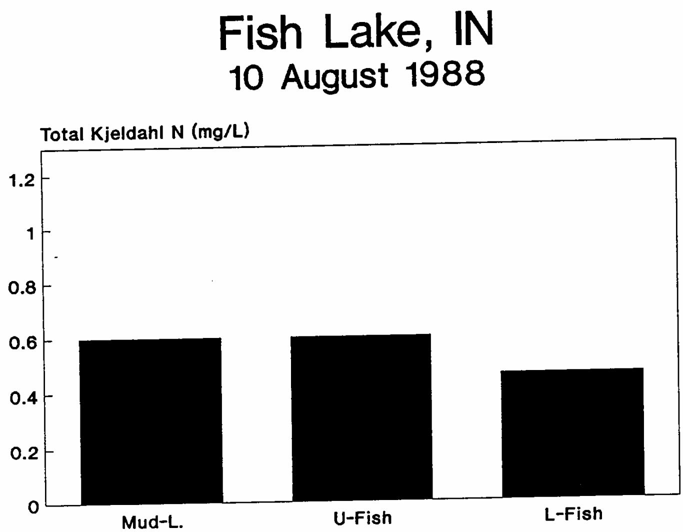
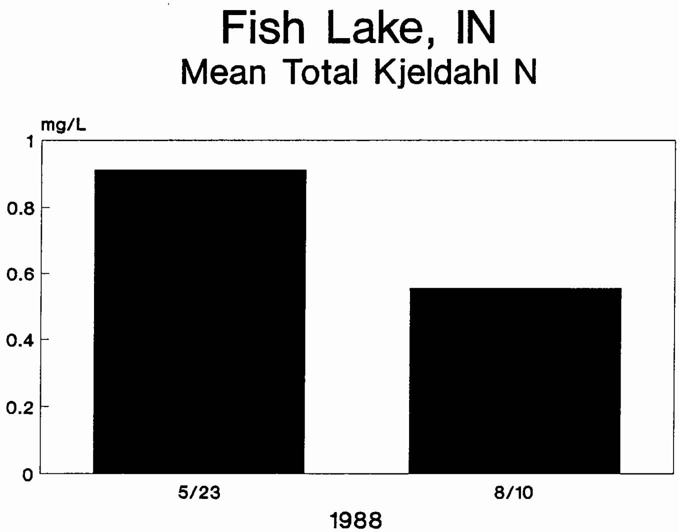


Figure 16. Kjeldahl Nitrogen Concentrations for Individual Basins of the Fish Lake System During May and August 1988.



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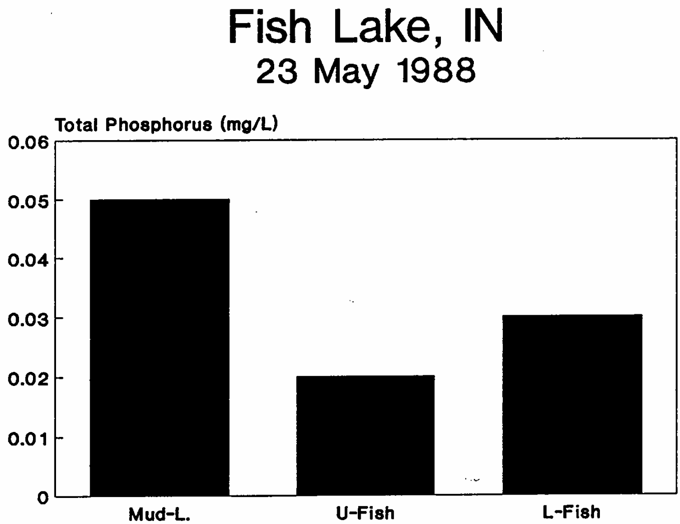


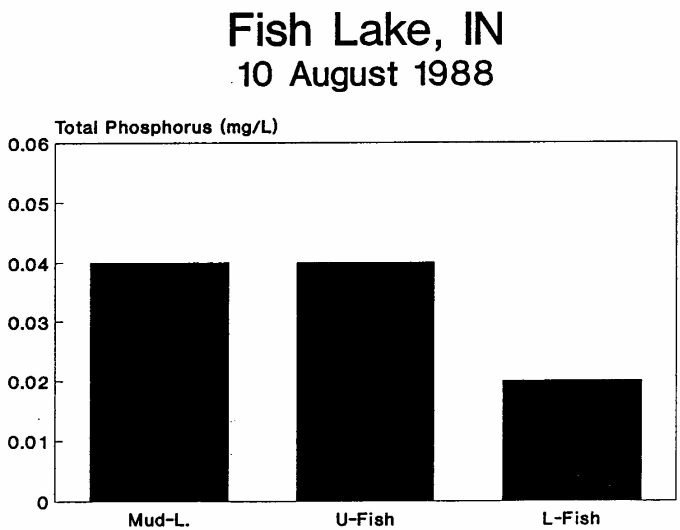


Figure 17. Total Phosphorus Concentrations for Individual Basins of the Fish Lake System During May and August 1988.

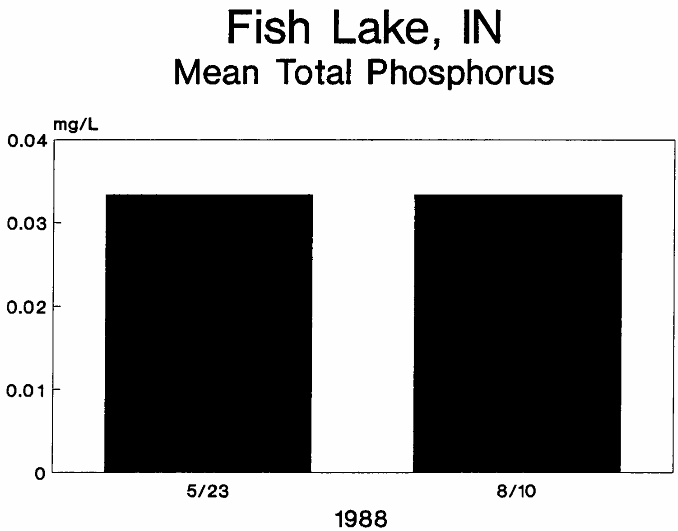
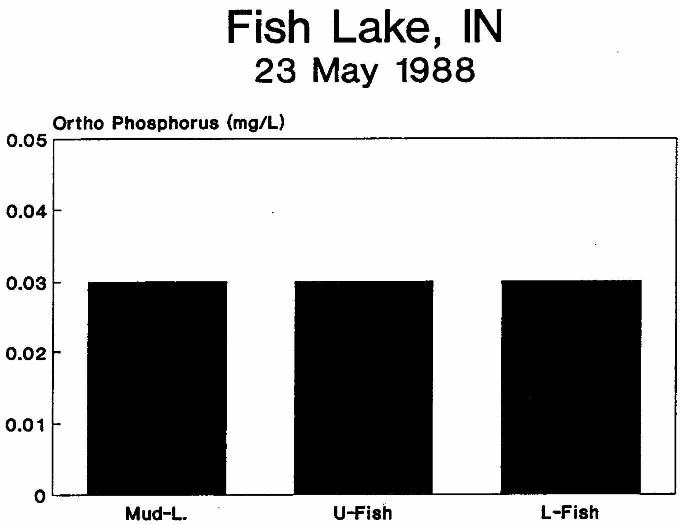


Figure 17. (Continued).



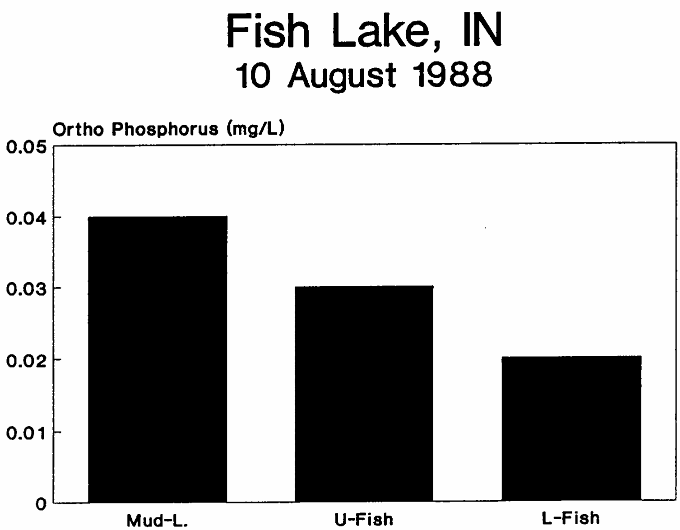


Figure 18. Ortho Phosphorus Concentrations for Individual Basins of the Fish Lake System During May and August 1988.

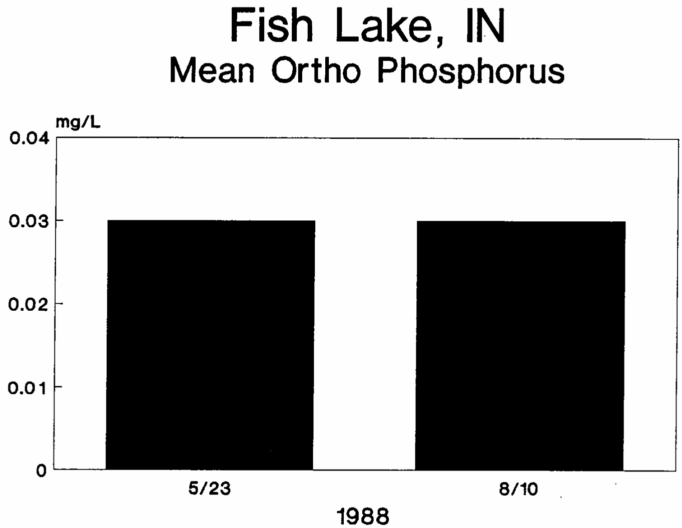
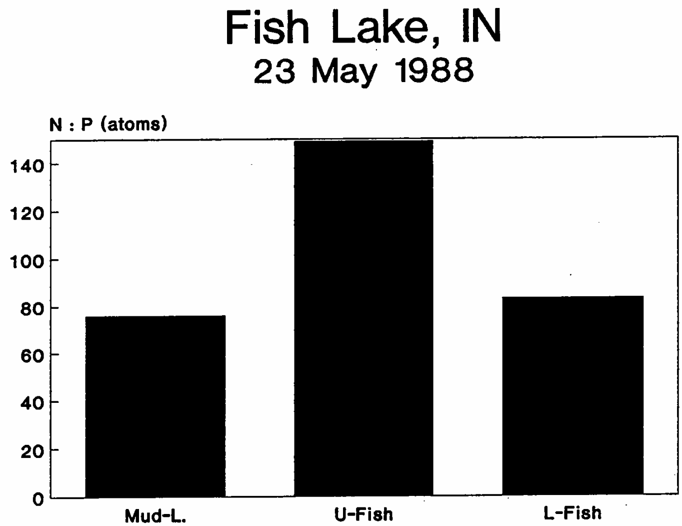


Figure 18. (Continued).



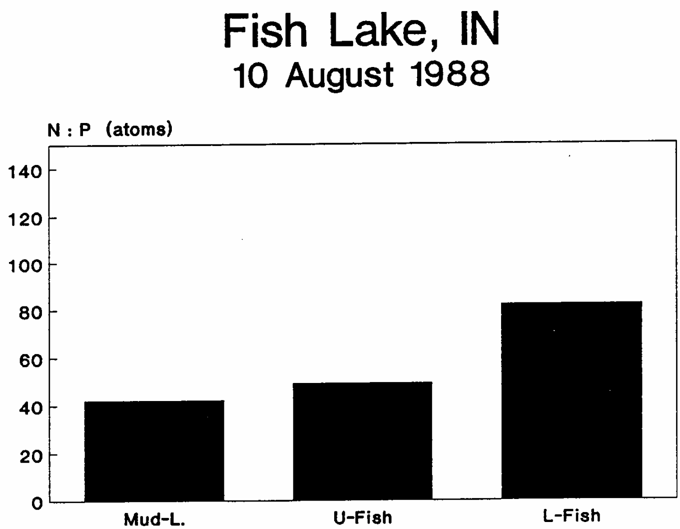


Figure 19. Nitrogen to Phosphorus Ratios for Individual Basins of the Fish Lake System During May and August 1988.

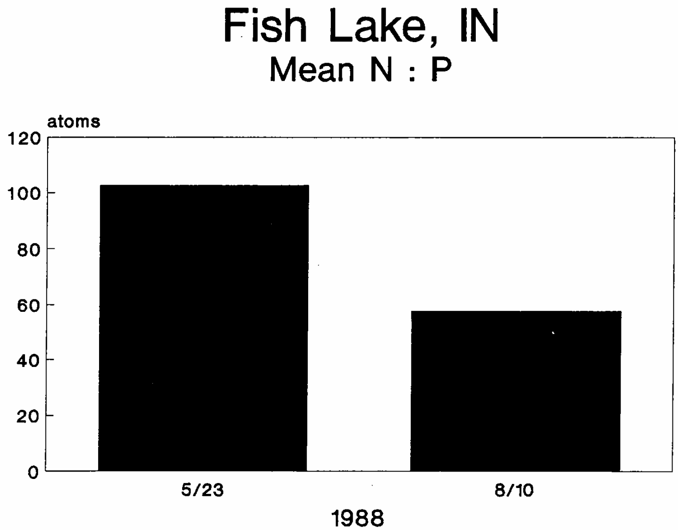
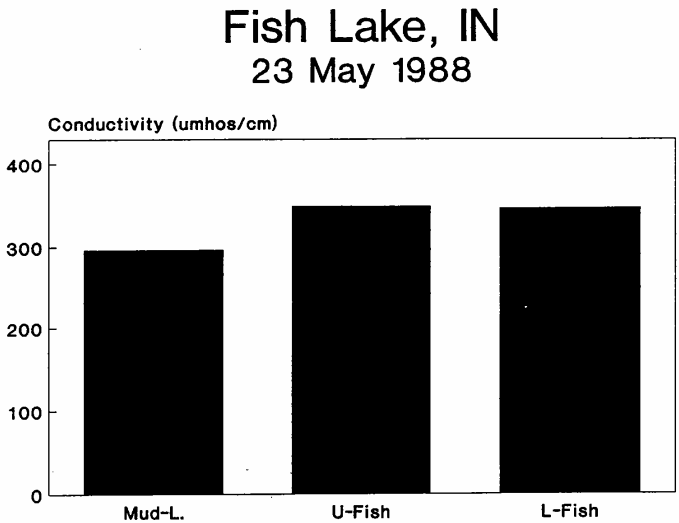


Figure 19. (Continued).



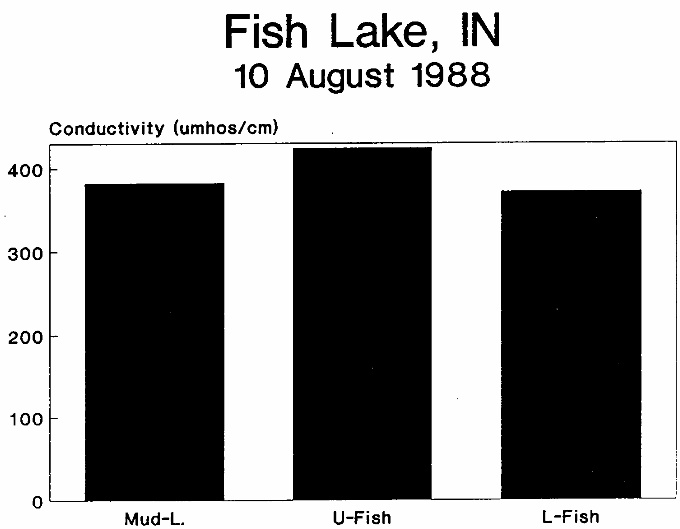


Figure 20. Conductivity Values for Individual Basins of the Fish Lake System During May and August 1988.

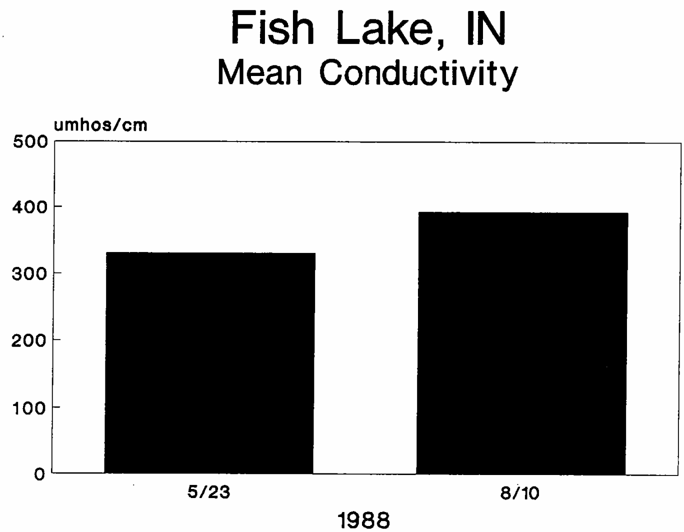


Figure 20. (Continued).

<u>Alkalinity</u>. Alkalinity was only measured during May 1988 (Figure 21). At that time, the basins were ranked in order of decreasing values as Upper Fish (180 mg/L), Lower Fish (160 mg/L), and Mud (160 mg/L). Although no values for May were found in the historical database, the May 1988 values were lower than recorded for any previous survey except June 1969. Alkalinity is indicative of the amount of carbonate rich material dissolved in the lake water. As most of this carbonate enters the lake via watershed runoff, the data are suggestive that watershed runoff during 1988 was lower the immediately preceding years. This is likely an artifact of the extreme drought conditions of 1988.

<u>Chlorophyll</u>. Chlorophyll is a good estimator of algal biomass in a lake. Chlorophyll concentrations were measured only during August 1988 (Figure 22). The three basins were ranked in order of decreasing chlorophyll values as Lower Fish (0.038 mg/L), Upper Fish (0.02 mg/m^3), and Mud (0.004 mg/m^3). Historical data for chlorophyll were unavailable for comparison with the 1988 database.

<u>IDEM Trophic State Index</u>

Mr Harold BonHomme of the Indiana Department of Environmental Management (IDEM) devised a eutrophication index specific to Indiana lakes based on summertime sampling of 307 lakes in the mid 1970's. Parameters included in the index construction were phosphorus, nitrogen forms, dissolved oxygen, light penetration and transmission, and phytoplankton abundance and group dominance. Ranges for each parameter were assigned eutrophy points, and the final eutrophication index value for a given lake represented the sum of eutrophy points from all parameters combined.

Mud Lake was not included in the 1975 survey of the Indiana Department of Environmental Management, thus historical eutrophication indices are lacking. In the current investigation, the eutrophication index for Mud Lake, as well as Upper Fish and Lower Fish, was calculated from parameters collected on a single sampling date (10 August) of 1988. The 1988 eutrophication index for Mud Lake was calculated as 19, assigning the basin to the category of best water quality, Class One (Table 11). Although a species composition was not provided, it was reported that the phytoplankton assemblage was dominated by blue-green algae.

The 1975 eutrophication index for Upper Fish Lake was calculated by the Indiana Department of Environmental Management as 22, thus assigning the lake to the category of best water quality, Class One. The eutrophication index for Upper Fish in 1988 was essentially the same and calculated as 23 (Table 12). The phytoplankton assemblage was dominated numerically by blue-green algae during both years. While the

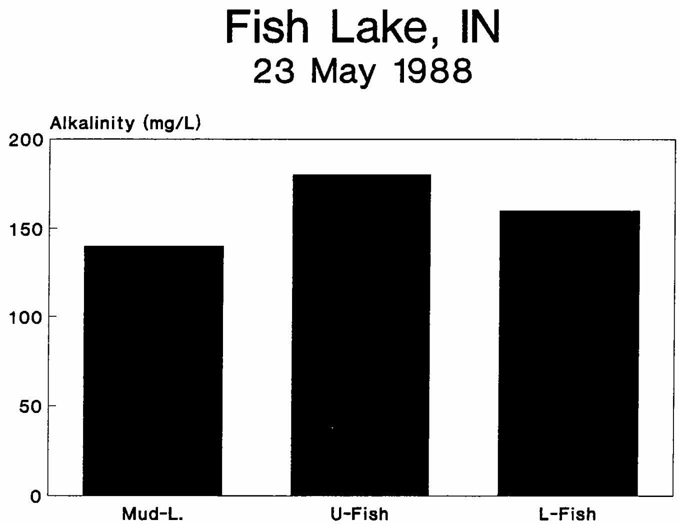


Figure 21. Alkalinity Values for Individual Basins of the Fish Lake System During May 1988.

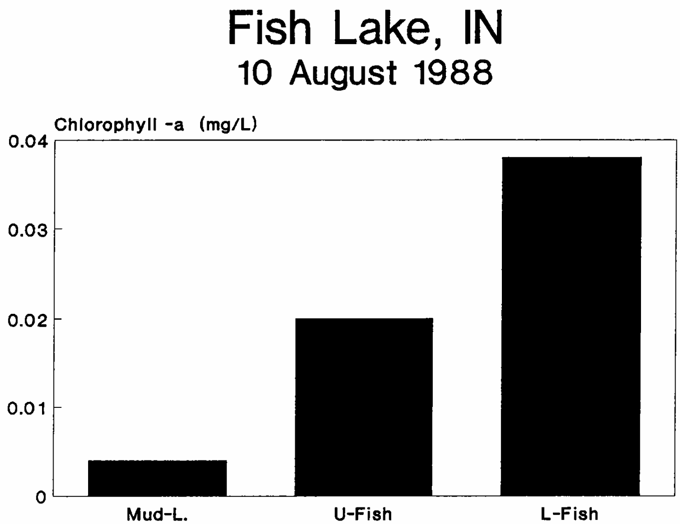


Figure 22. Chlorophyll Values for Individual Basins of the Fish Lake System During August 1988.

Table 11. 1988 Eutrophication Index for Mud Lake.

ISBH LAKE EUTROPHICATION INDEX---------Mud Lake

	Parameter	Measured Value (units)	Eutrophy Points
I.	Total Phosphorus	0.04 ppm	2
II.	Soluble Phosphorus	0.04 ppm	2
III.	Organic Nitrogen	0.6 ppm	2
IV.	Nitrate	<.01 ppm	0
V.	Ammonia	0.16 ppm	0
VI.	Dissolved Oxygen Saturation at five feet from surface	72 %	0
VII.	Dissolved Oxygen (% measured water column with >0.1 ppm DO)	100 %	0
VIII.	Light Penetration (Secchi Disk)	6.6 feet	0
IX.	Light Transmision (Depth of 1% transmittance)	16.4 feet	2
X.	Total Plankton		
X(a).	Vertical tow, 5 ft to surface	755 cells/mL	1
	Blue-green dominance?	Yes	5
X(b).	Vertical tow, thermocline to surface	468 cells/mL	0
	Blue-green dominance?	Yes	5
		LEI=	19

Table 12. 1988 Eutrophication Index for Upper Fish Lake.

ISBH LAKE EUTROPHICATION INDEX---------Fish Lake-Upper Basin

	Parameter	Measured Value (units)	Eutrophy Points
I.	Total Phosphorus	0.04 ppm	2
II.	Soluble Phosphorus	0.03 ppm	1
III.	Organic Nitrogen	0.6 ppm	2
IV.	Nitrate	<.01 ppm	0
V.	Ammonia	0.29 ppm	0
VI.	Dissolved Oxygen Saturation at five feet from surface	95 %	0
VII.	Dissolved Oxygen (% measured water column with >0.1 ppm DO)	86 %	0
VIII.	Light Penetration (Secchi Disk)	4.9 feet	6
IX.	Light Transmision (Depth of 1% transmittance)	12.3 feet	2
X.	Total Plankton		
X(a).	Vertical tow, 5 ft to surface	306 cells/mL	0
	Blue-green dominance?	Yes	5
X(b).	Vertical tow, thermocline to surface	402 cells/mL	0
	Blue-green dominance?	Yes	5
		LEI =	23

1975 phytoplankton assemblage was dominated numerically by Oscillatoria, the 1988 midsummer assemblage was dominated by Anacystis with Anabaena and Lyngbya as the principal subdominant blue-green taxa.

As with Upper Fish, the eutrophication index for Lower Fish Lake appears to have remained unchanged between 1975 (8) and 1988 (7) (Table 13). Although all three basins were assigned to the category of best water quality, Class One, Lower Fish clearly was the least eutrophic. Of the three basins examined, Lower Fish is the only one that did not display great abundance of blue-green algae in both 1975 and 1988. The numerically dominant taxon in 1975 was Ceratium, and Anacystis and Anabaena were the only two blue-green genera identified. Although the 1988 survey noted dominance by blue-greens, no species composition data were provided.

While it appears that water quality in the Fish Lake system as indicated by the IDEM eutrophication index appears to have changed little since at least 1975, such an interpretation must be approached cautiously. It is must be remembered, however, that the eutrophication index is an estimate of the water column conditions in open water, and like all indices, does not include the extent and productivity of aquatic weeds. In addition, the parameters needed for index construction were collected on a single date during the height of the heat and drought of 1988 and may not give a true estimate of conditions under normal environmental conditions. Finally, parameters for the 1988 index calculation were identical to those used for the 1975 index with the exception of light penetration, which was measured with a photocell in 1975 and was approximated in 1988 by multiplying the Secchi disc reading by 2.5. The latter is considered a crude estimate of the 1% light level and is not directly comparable to calculations based directly from photocells. The importance of this methodological difference on calculated eutrophication indices is not known.

Stream Chemistry

Two streams were sampled during the 1988 survey (figure page ix). Fish Creek drains the northwestern portion of the Fish Lake watershed (2825 acres). Approximately 68% of its drainage is devoted to pasture and row crops, and wetlands, principally peat bogs, comprise an additional 21% of the area. The latter have undergone extensive draining and mining for peat since approximately 1968. Fish Creek enters Upper Fish Lake along the northern shore, a shallow area displaying extremely dense macrophyte growth. Fish Creek was sampled at two sites: site one labelled "at peat bog" but exact location not specified and site two where the creek flows under County Road 200 S. We have assumed that the location of site one was where County Road 775 E. crosses

Table 13. 1988 Eutrophication Index for Lower Fish Lake.

ISBH LAKE EUTROPHICATION INDEX---------Fish Lake-Lower Basin

	Parameter	Measured Value (units)	Eutrophy Points
I.	Total Phosphorus	0.02 ppm	0
II.	Soluble Phosphorus	0.02 ppm	0
III.	Organic Nitrogen	0.46 ppm	0
IV.	Nitrate	0.02 ppm	0
V.	Ammonia	0.26 ppm	0
VI.	Dissolved Oxygen Saturation at five feet from surface	103 %	0
VII.	Dissolved Oxygen (% measured water column with >0.1 ppm DO)	100 %	0
VIII.	Light Penetration (Secchi Disk)	5.9 feet	0
IX.	Light Transmision (Depth of 1% transmittance)	14.8 ft	2
X.	Total Plankton		
X(a).	Vertical tow, 5 ft to surface	123 cells/mL	0
	Blue-green dominance?	Yes	5
X(b).	Vertical tow, thermocline to surface	88 cells/mL	0
	Blue-green dominance?	No	0
		LEI=	7

the creek.

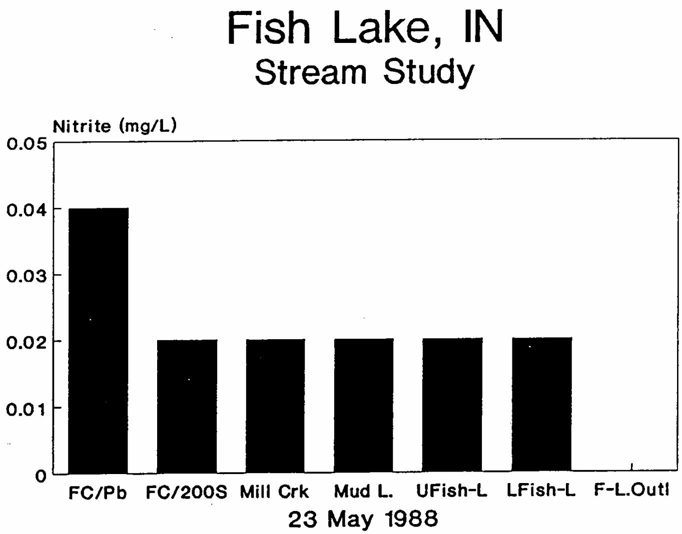
Mill Creek is a highly channelized stream that drains a 1158 acre segment of the watershed northeast of Upper Fish Lake. Approximately 56% of the watershed is devoted to row crops and pasture with wetlands contributing an additional 29% of the area. This stream enters Upper Fish Lake along the northern shore just east of the inlet for Fish Creek. This section of the lake is shallow with dense macrophytes. Only one site was collected in Mill Creek, but the exact location was not provided. Given the sampling design for Fish Creek, I feel it is reasonable to assume that sampling was at the bridge for County Road 200 S.

Water chemistry data for Fish Creek and Mill Creek were collected twice during 1988: 23 May and 10 August. Concurrent samples were collected in Mud Lake, Upper Fish Lake, Lower Fish Lake, and the outlet for the Fish Lake system along the southern shore of Lower Fish Lake. The lake outlet was not sampled in May, and the peat bog site of Fish Creek and Mill Creek were not sampled in August. Stream data were also supposed to be collected during storm events, but because of the extreme drought of 1988, only a minor event on 19 September was sampled. The following discussion compares stream water chemistry with that of lake and outlet stations for individual sampling dates.

Nitrite concentrations in Fish Creek at the peat bog were approximately double (0.04 vs 0.02 mg/L) those measured at any lake or other stream station on 23 May (Figure 23). It is interesting that nitrite values were reduced 50% between the peat bog and 200 S stations in Fish Creek and were comparable with those of Mill Creek and all lake stations. Nitrite values at all stations on 10 August were less than 0.01 mg/L. Unfortunately, data for the peat bog station were missing.

As noted for nitrite, nitrate concentrations at the peat bog station of Fish Creek greatly exceeded (3-4 times) those of either the lakes or the other creek stations during May 1988 (Figure 24). Values in Fish Creek declined by approximately 75% between the peat bog and County Road 200 S stations but were still greater than noted for Mill Creek or any of the lake stations. It is unfortunate that the peat bog station was not sampled during August to determine if this station continued to be a large nitrogen exporter.

Unlike nitrite and nitrate, ammonia at the peat bog station of Fish Creek during May 1988 was lower than at any other creek or lake station (Figure 25). Fish Creek, however, at the County Road 200 S station did display greater ammonia than Mill Creek. Because of the spotty sampling regime, it is difficult to make direct comparisons between May and August samplings.



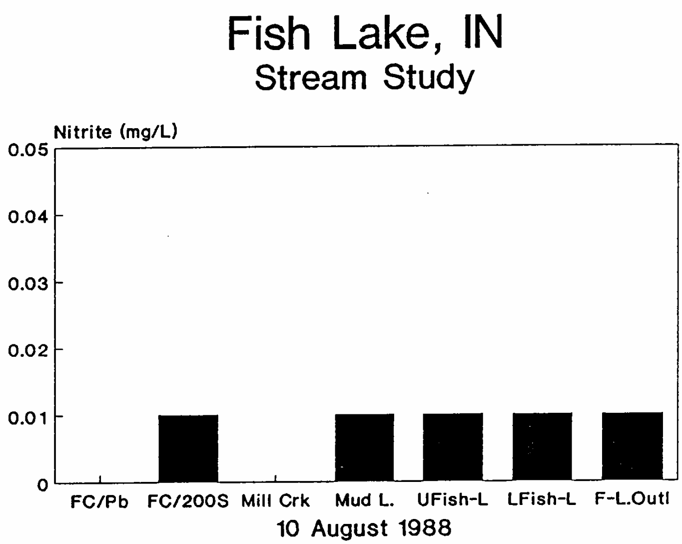
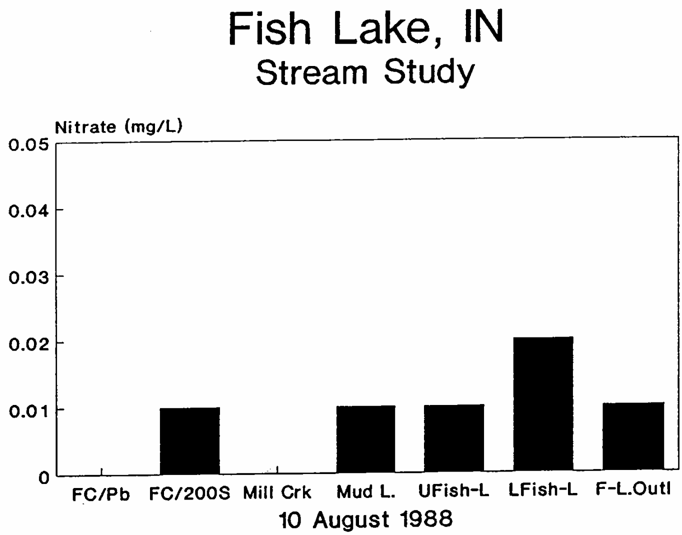


Figure 23. Nitrite Concentrations for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).



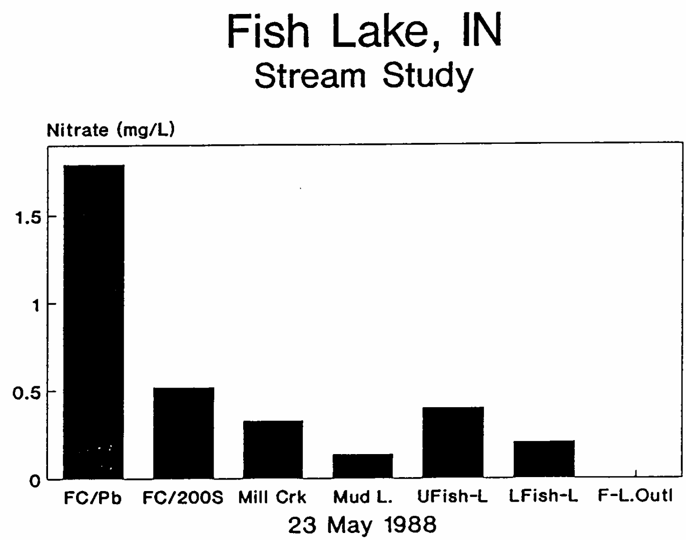
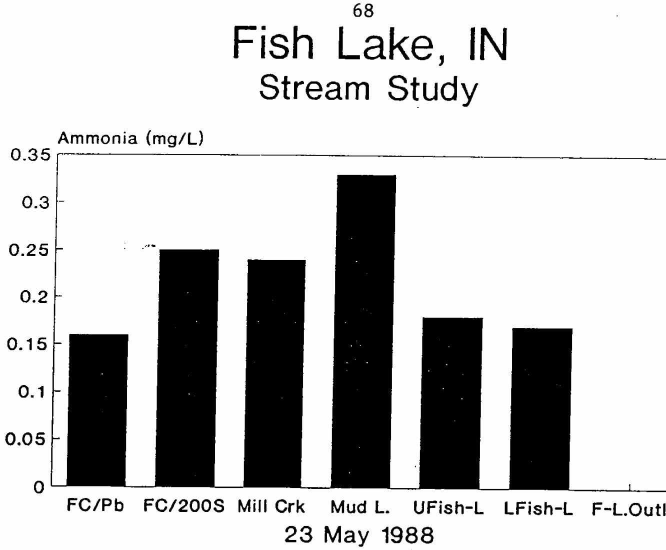


Figure 24. Nitrate Concentrations for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).



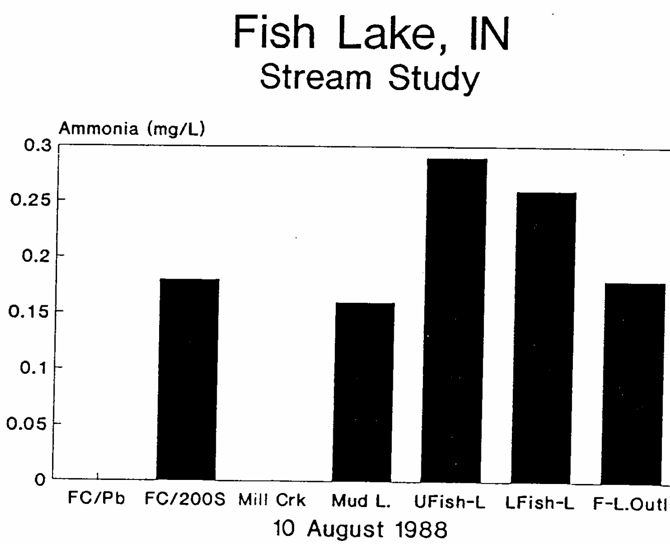


Figure 25. Ammonia Concentrations for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

Kjeldahl nitrogen values are missing for all stream stations during May and for the peat bog station of Fish Creek and Mill Creek during August (Figure 26). Regarding the lake, however, it is interesting to note that outlet values were greater than noted in any of the three lake basins. The only stream data for Kjeldahl nitrogen was on 19 September 1988 following one of the infrequent storm events of the drought period (Figure 27). At that time, both Fish Creek and Mill Creek had comparable (0.05 mg/L) values. Again, such are data are insufficient to evaluate the export from the peat bog draining into Fish Creek.

The lowest total phosphorus value of any stream site during May 1988 was for the peat bog site of Fish Creek (Figure 28). Phosphorus increased along the length of Fish Creek and was even greater in Mill Creek (0.27 mg/L). Only one stream site was sampled in August (Fish Creek at 200 S) so no stream trends could be determined. Within the Fish Lake system, however, total phosphorus decreased from north to south in the system with the lowest value reported from the outlet (0.01 mg/L). Total phosphorus in both Fish Creek and Mill Creek following the September was 0.05 mg/L (Figure 29).

While orthophosphorus values remained at 0.03 mg/L at all other sites, Mill Creek during May displayed a value of 0.13 mg/L (Figure 30). The high values for both total phosphorus and orthophosphorus at the latter site may be a reflection of fertilization for row crops during the immediately prior period. As with total phosphorus, orthophosphorus concentrations decreased from north to south in the Fish Lake system during August with the lowest value being reported for the outlet. At least during the summer of 1988, Fish Lake appears to be actively trapping phosphorus delivered from the watershed.

As mentioned previously in this report, the ratio of total nitrogen to total phosphorus can be useful in delineating which of these two essential nutrients is limiting photosynthetic activity (algae or macrophytes) in aquatic systems. Such ratios could be calculated only for the August data, even then both Mill Creek and the peat bog site of Fish Creek were missing (Figure 31). All stations were characterized by N:P ratios greater than 10, suggesting that phosphorus is the most likely nutrient limiting photosynthetic activity. It is interesting to note, however, that N:P ratios increased progressively from north to south in the Fish Lake system suggesting more pronounced phosphorus limitation in Lower Fish lake. Such a finding is not unexpected given the relatively oligotrophic condition of this basin.

Total suspended solids were greatest (28 mg/L) in Mill

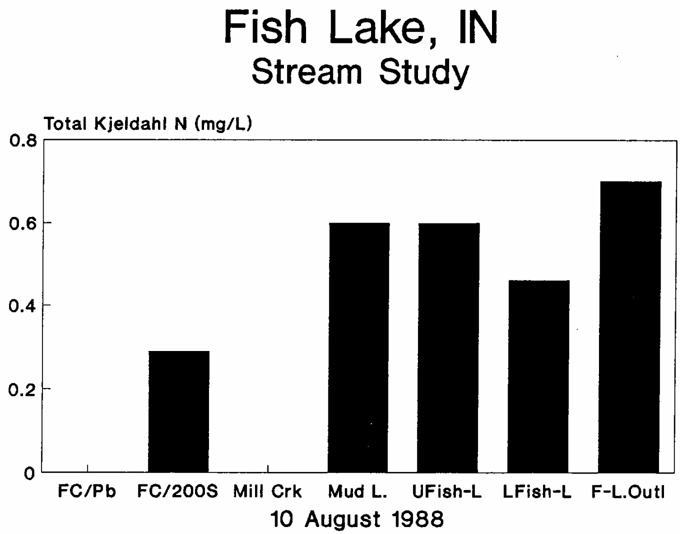


Figure 26. Total Kjeldahl Nitrogen Concentrations for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

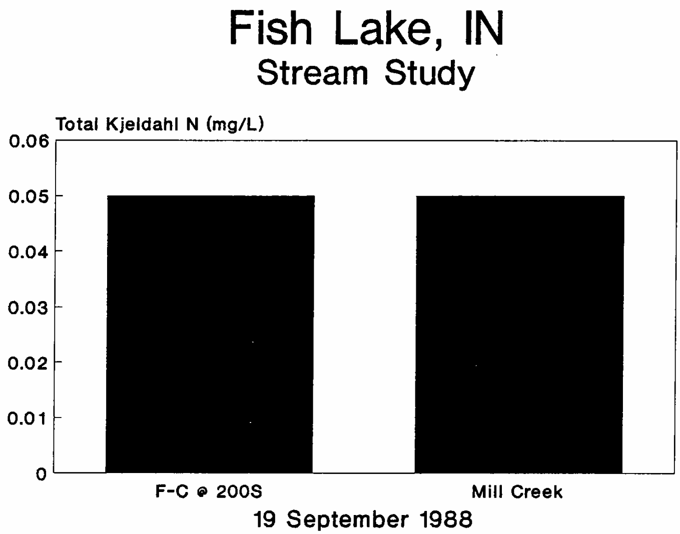
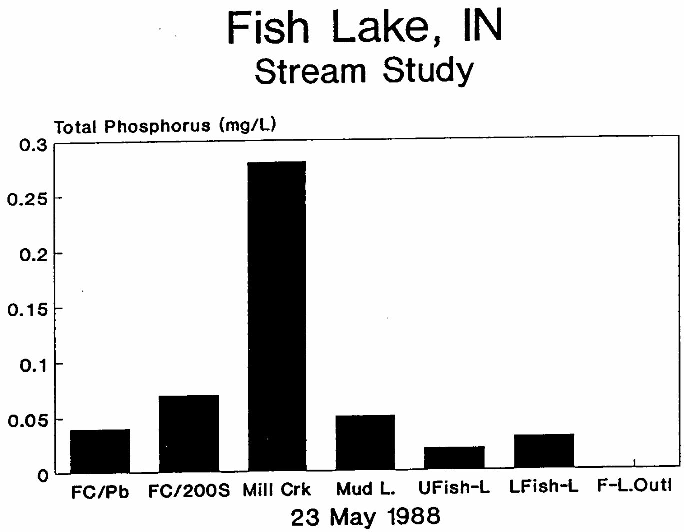


Figure 27. Total Kjeldahl Nitrogen Values for Fish Creek at Road 200 S (FC @ 200S) and Mill Creek During September 1988.



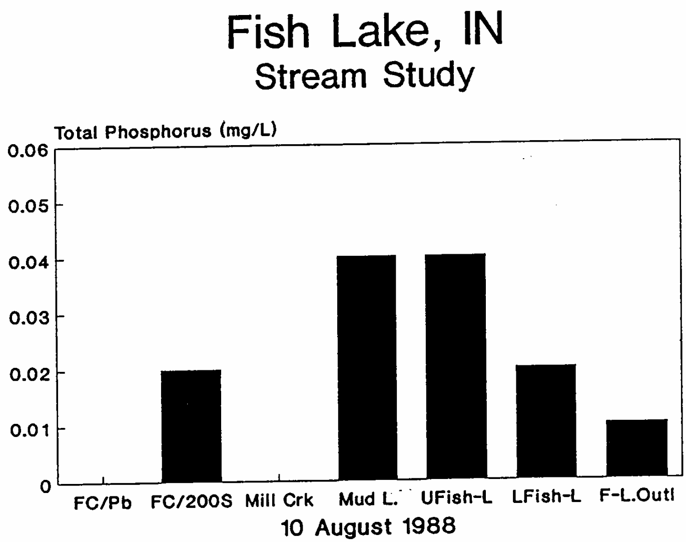


Figure 28. Total Phosphorus Concentrations for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

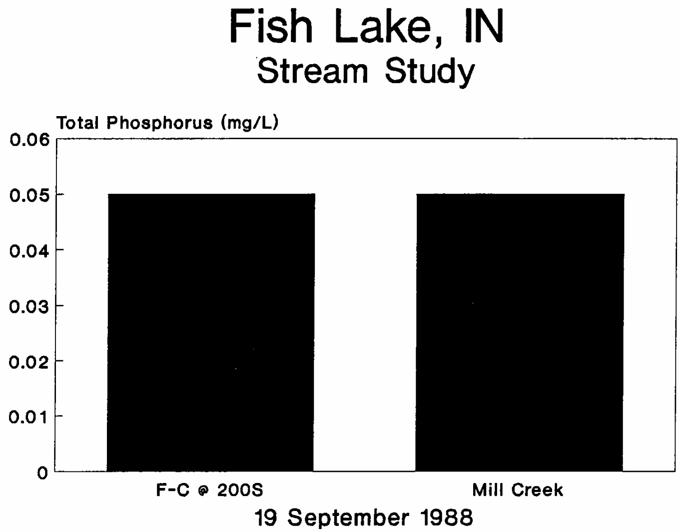
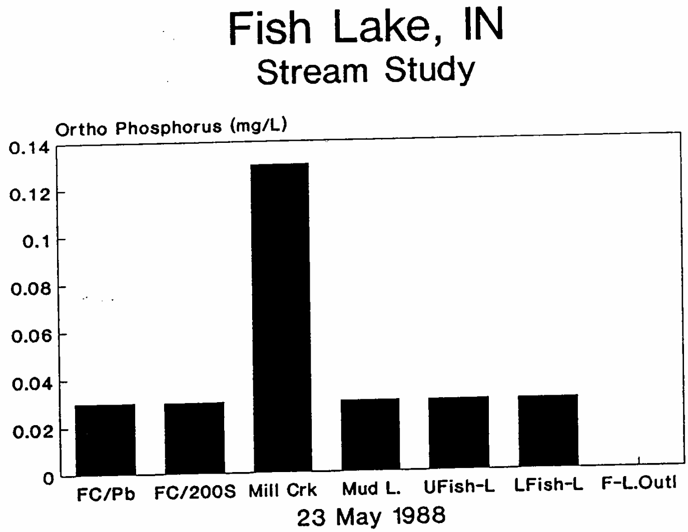


Figure 29. Total Phosphorus Values for Fish Creek at Road 200 S (FC @ 200S) and Mill Creek During September 1988.



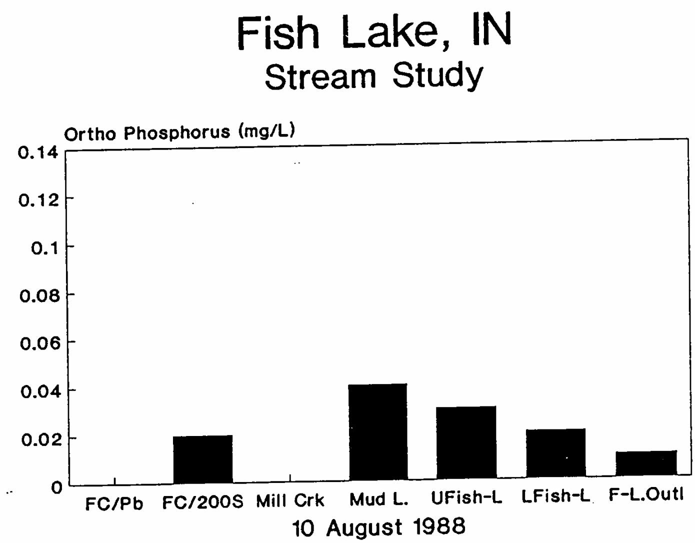


Figure 30. Ortho Phosphorus Concentrations for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

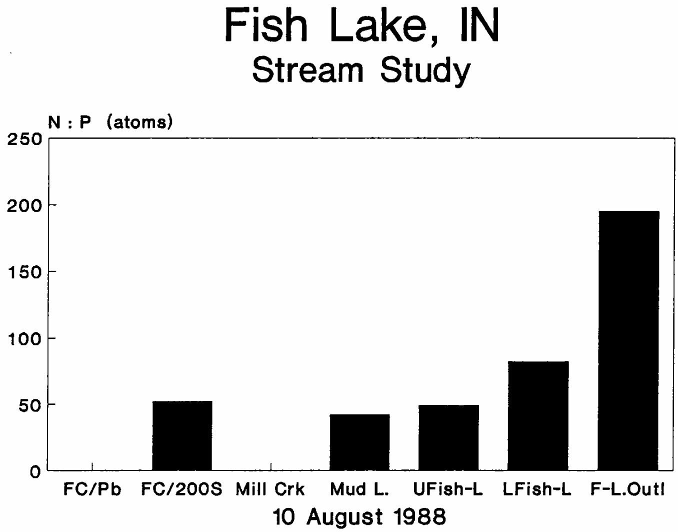


Figure 31. Nitrogen to Phosphorus Ratios for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

Creek during May (Figure 32). This supports the earlier contention that the high phosphorus concentrations in this creek during May were directly related to row crop agricultural practices. Values were lower in Fish Creek but little difference was noted between the two sites (13-14 mg/L). All creek sites were were an order of magnitude greater than values characterizing any of the lake sites during May. The TSS value for Fish Creek was markedly lower during August as a direct reflection of the extreme drought conditions. During both May and August, TSS values were greater in Lower Fish than Upper Fish. Following the storm event of September, Mill Creek again had higher TSS than found in Fish Creek (Figure 33).

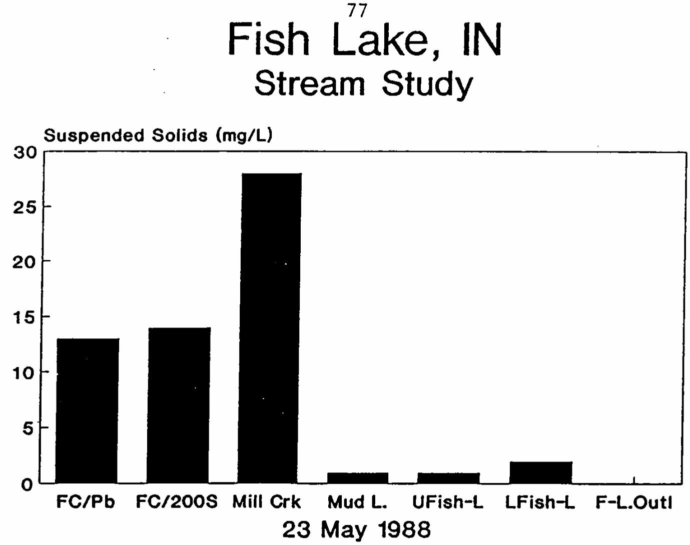
Chlorophyll was measured only during August and from the Fish Creek station at County Road 200 S (Figure 34). At that time chlorophyll in Fish Creek was greater than measured from any lake station except Lower Fish, and its degradation product, pheophytin, was greater than all lake stations. For both parameters, values increased progressively southward through the Fish Lake system, possibly reflecting a concurrent decrease in the biomass of macrophytes. The fact that Fish Creek displayed greater algal biomass than found in the lake basins may reflect the fact that stream flow due to the drought was so reduced as to permit pooling and development of large algal blooms in the stream channel. Other lakes in Indiana (Koontz) developed such a pattern during the same time period.

Microbiology

Microbiological samples were collected only on 10 August 1988. The County Road 200 S site of Fish Creek was the only stream station. Lake stations included Mud Lake, Upper Fish Lake, Lower Fish Lake, and the outlet from Lower Fish Lake. Details on sampling methodology were not provided to the author by Turnbell Engineering. Data provided for fecal coliform bacteria indicate that all stations sampled were within state standards on 10 August with the lowest value (125 mpn/100 mL) found in Lower Fish Lake (Figure 35). Fish Creek was within the range characterizing the Fish Lake system.

Fecal streptococcus were an order of magnitude greater in Fish Creek than at any lake station but were not considered a problem (Figure 36). Such high levels at the stream site resulted in the lowest FC:FS ratio of any sites sampled (Figure 37). The FC:FS ratio is often used to separate the contribution of animal versus human sources. Unfortunately, the current data were too scant to make any definitive conclusions as to source.

Five-day Biochemical Oxygen Demand (BOD) was run on lake and stream station during both May and August 1988



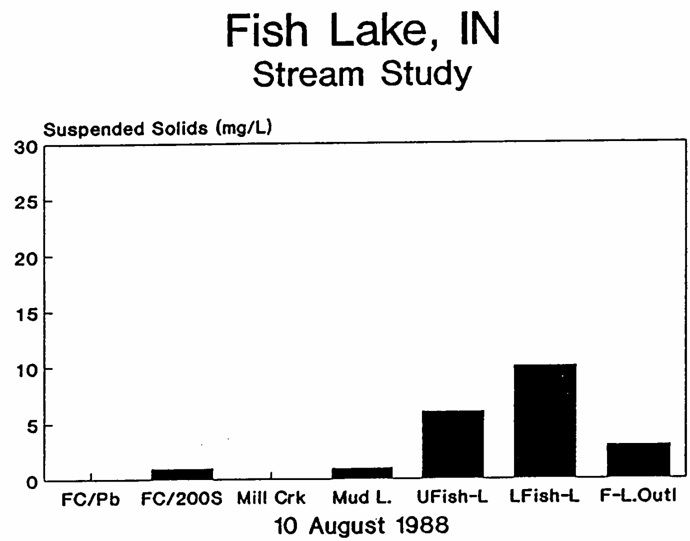


Figure 32. Total Suspended Solids Values for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

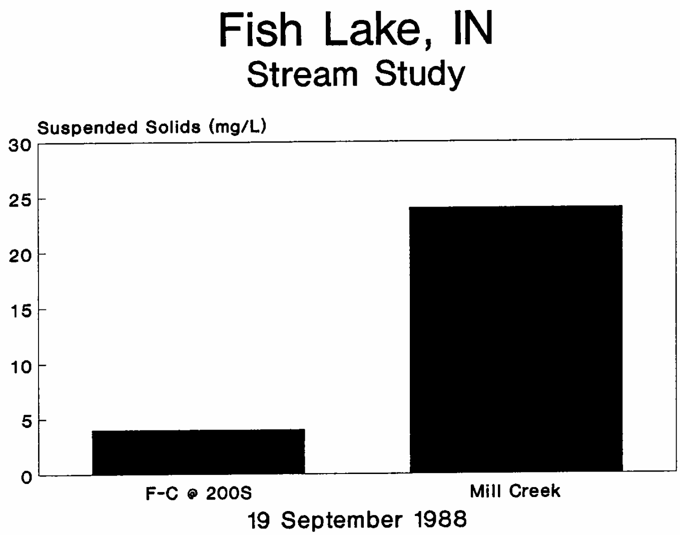
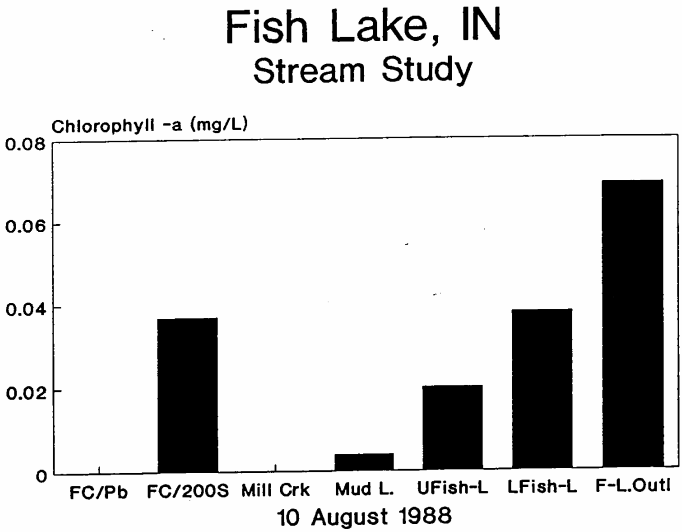


Figure 33. Total Suspended Solids Values for Fish Creek at Road 200 S (FC @ 200S) and Mill Creek During September 1988.



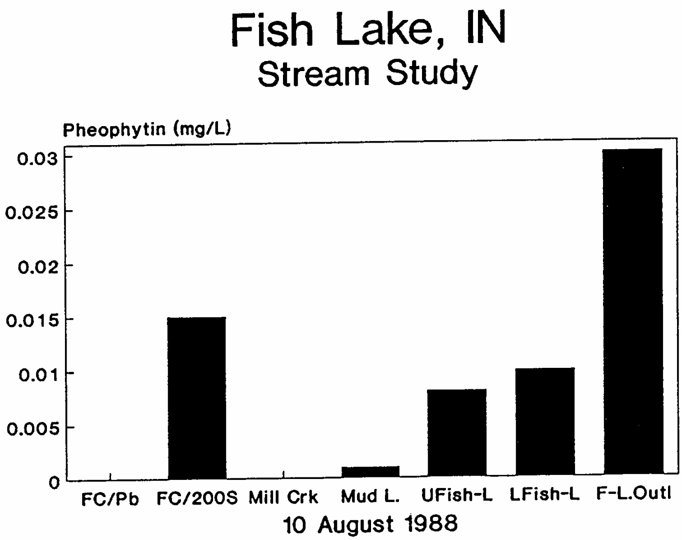


Figure 34. Chlorophyll and Pheophytin Values for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

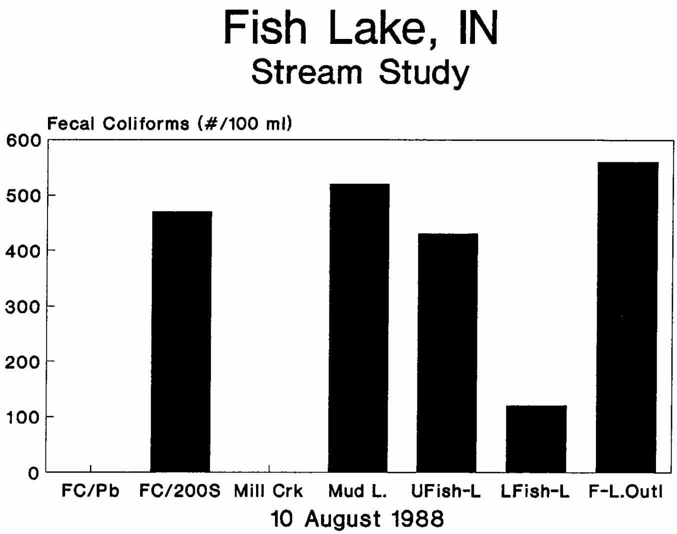


Figure 35. Fecal Coliform Values for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

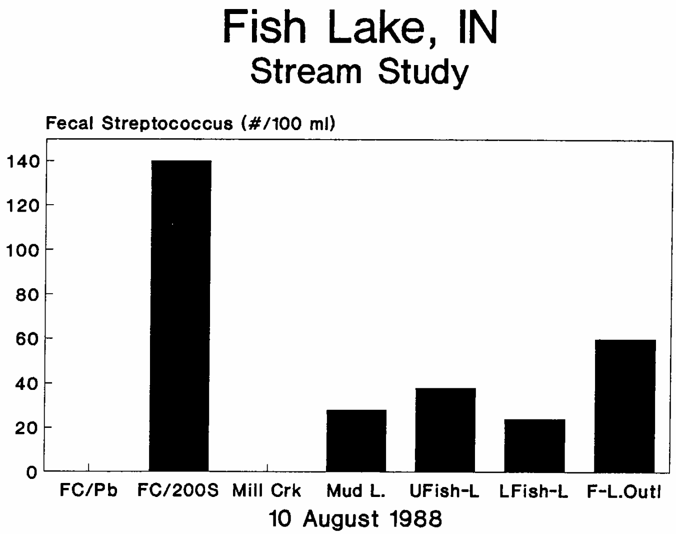


Figure 36. Fecal Streptococcus Values for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

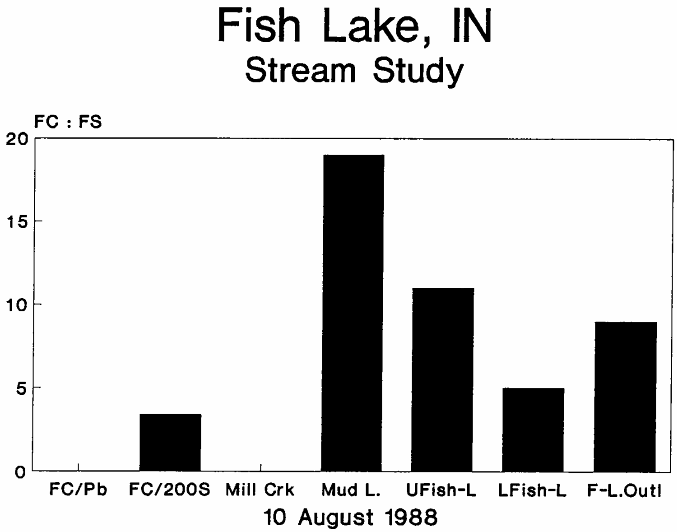


Figure 37. Fecal Coliform to Fecal Streptococcus Ratios for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

(Figure 38). The highest BOD value for any stream station during May was from the peat bog site on Fish Creek and may reflect release of organic matter upstream from this location. Stream and lake stations were roughly comparable during May, but Fish Creek value for August was approximately four times greater than any lake station during August. Such data are extremely spotty except to note that no BOD value was considered excessive high during the late spring and summer of 1988.

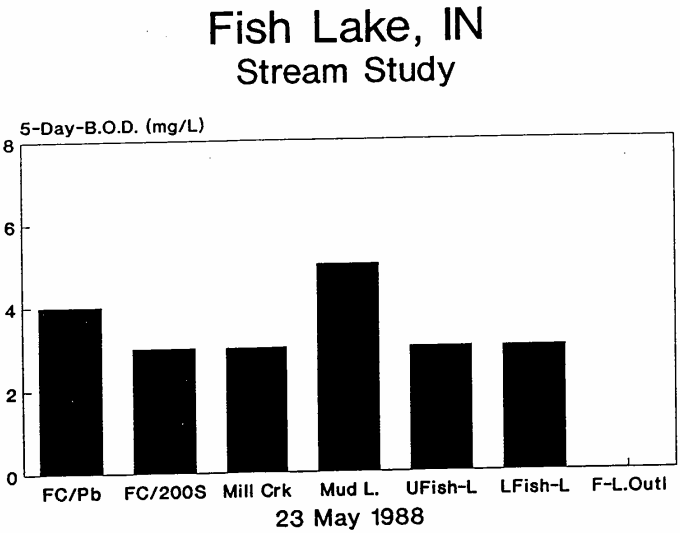
One can not conclude a great deal from the microbiological testing for the Fish Lake system and watershed. Although serious bacterial contamination was not noted in 1988, additional testing would have to be performed in order to make any definitive statements as its severity during a "normal" year.

Macrophytes

No data on the species composition and aerial extent of aquatic macrophytes during 1988 were provided. I assume that coontail (Ceratophyllum) and milfoil including the exotic Eurasian milfoil (Myriophyllum spicatum) continue to be the dominant macrophytes in 1988 at depths 4-8 feet as noted by the DNR in 1984 (Table 6).

Sediment Contaminants

A total of 35 volatile compounds were examined from Upper Fish Lake sediments (Table 14). Only two were above the detection limits of the instrumentation, methylene chloride and 2-Butanone, but not at extremely elevated values. In addition, none of the 65 semi-volatile compounds (Table 15) and 25 pesticides (Table 16) had concentrations exceeding the baseline sensitivity of the instrumentation. Finally, 6 (antimony, chromium, lead, nickel, thallium, zinc) of the 15 priority pollutants were at detectable levels but none were considered to be of health concern (Table 17).



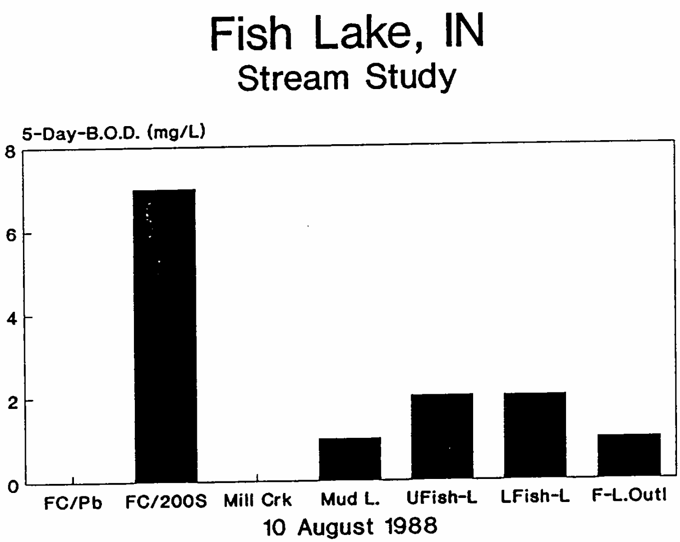


Figure 38. Five Day Biochemical Oxygen Demand (BOD) Values for Individual Stream and Lake Stations and the Fish Lake Outlet. Stream Stations Were Fish Creek at the Peatbog (FC/Pb), Fish Creek at Road 200 S (FC/200S) and Mill Creek (Mill Crk).

Table 14. Concentrations of Volatile Compounds in Sediments of Upper Fish Lake

VOLATILE COMPOUNDS
ANALYTICAL RESULTS

ATEC Lab No. 81848 VOA

Analyte	CAS Number	Concentration (ug/kg)	Quantitation Limit (ug/kg)
Chloromethane	74-87-3	<42	42
Bromomethane	74-83-9	<42	42
Vinyl Chloride	75-01-4	<42	42
Chloroethane	75-00-3	<42	42
Methylene Chloride	75-09-2	38	21
Acetone	67-64-1	<42	42
Carbon Disulfide	75-15-0	<21	21
1,1-Dichloroethene	75-35-4	<21	21
1,1 Dichloroethane	75-35-3	<21	21
Trans-1,2-Dichloroethene	156-60-5	<21	21
Chloroform	67-66-3	<21*	21
1,2-Dichloroethane	107-06-2	<21	21
2-Butanone	78-93-3	76	42
1,1,1-Trichloroethane	71-55-6	<21	21
Carbon Tetrachloride	56-23-5	<21	21
Vinyl Acetate	108-05-4	<42	42
Bromodichloromethane	75-27-4	<21	21
1,2-Dichloropropane	78-87-5	<21	21
Trans-1, 3-Dichloropropene	10061-02-6	<21	21
Trichloroethene	79-01-6	<21	21
Dibromochloromethane	124-48-1	<21	21
1,1,2-Trichloroethane	79-00-5	<21	21
Benzene	71-43-2	<21	21
cis-1,3-Dichloropropene	10061-01-5	<21	21
2-Chloroethylvinylether	110-75-8	<42	42
Bromoform	75-25-2	<21	21
4-Methyl-2-Pentanone	591-78-6	<42	42
2-Hexanone	108-10-1	<42	42
Tetrachloroethene	127-18-4	<21	21
1,1,2,2-Tetrachloroethane	79-34-5	<21	21
Toluene	108-88-3	<21*	21
Chlorobenzene	108-90-7	<21	21
Ethylbenzene	100-41-4	<21*	21
Styrene	100-42-5	<21	21
Total Xylenes		<21	21

* Analyte detected but amount present is less than the Quantitation Limit.

Analytical Method: SW 846 Method 8240

Table 15. Concentrations of Semi-Volatile Compounds in Sediments of Upper Fish Lake

SEMI-VOLATILE COMPOUNDS
ANALYTICAL RESULTS

ATEC Lab No. 81848

Analyte	CAS Number	Concentration (ug/kg)	Quantitation Limit (ug/kg)
Phenol	108-95-2	<330	330
bis(2-Chloroethyl) Ether	111-44-4	<330	330
2-Chlorophenol	95-57-8	<330	330
1,3-Dichlorobenzene	541-73-1	<330	330
1,4-Dichlorobenzene	106-46-7	<330	330
Benzyl Alcohol	100-51-6	<330	330
1,2-Dichlorobenzene	95-50-1	<330	330
2-Methylphenol	95-48-7	<330	330
bis(2-chloroisopropyl) Ether	39638-32-9	<330	330
4-Methylphenol	106-44-5	<330	330
N-Nitroso-Di-n-propylamine	621-64-7	<330	330
Hexachloroethane	67-72-1	<330	330
Nitrobenzene	98-95-3	<330	330
Isophorone	78-59-1	<330	330
2-Nitrophenol	88-75-5	<330	330
2,4-Dimethylphenol	105-67-9	<330	330
Benzoic Acid	65-85-0	<1600	1600
bis(2-chloroethoxy) Methane	111-91-1	<330	330
2,4-Dichlorophenol	120-83-2	<330	330
1,2,4-Trichlorobenzene	120-82-1	<330	330
Naphthalene	91-20-3	<330	330
4-Chloroaniline	106-47-8	<330	330
Hexachlorobutadiene	87-68-3	<330	330
4-Chloro-3-methylphenol	59-50-7	<330	330
2-Methylnaphthalene	91-57-6	<330	330
Hexachlorocylopentadiene	77-47-4	<330	330
2,4,6-Trichlorophenol	88-06-2	<330	330
2,4,5-Trichlorophenol	95-95-4	<1600	1600
2-Chloronaphthalene	91-58-7	<330	330
2-Nitroaniline	88-74-4	<1600	1600
Dimethyl Phthalate	131-11-3	<330	330
Acenaphthylene	208-96-8	<330	330
3-Nitroaniline	99-09-2	<1600	1600
Acenaphthene	83-32-9	<330	330
2,4-Dinitrophenol	51-28-5	<1600	1600
4-Nitrophenol	100-02-7	<1600	1600
Dibenzofuran	132-64-9	<330	330
2,4-Dinitrotoluene	121-14-2	<330	330
2,6-Dinitrotoluene	606-20-2	<330	330
Diethylphthalate	84-66-2	<330	330
4-Chlorophenyl-phenylether	7005-72-3	<330	330
Fluorene	86-73-7	<330	330
4-Nitroaniline	100-01-6	<1600	1600
4,6-Dinitro-2-methylphenol	534-52-1	<1600	1600

Table 15. (Continued)

Analyte	CAS Number	Concentration (ug/kg)	Quantitation Limit (ug/kg)
N-Nitrosodiphenylamine	86-30-6	<330	330
4-Bromophenyl-phenylether	101-55-3	<330	330
Hexachlorobenzene	118-74-1	<330	330
Pentachlorophenol	87-86-5	<1600	1600
Phenanthrene	85-01-8	<330	330
Anthracene	120-12-7	<330	330
Di-n-Butylphthalate	84-74-2	<330	330
Fluoranthene	206-44-0	<330	330
Pyrene	129-00-0	<330	330
Butylbenzylphthalate	85-68-7	<330	330
3,3'-Dichlorobenzidine	91-94-1	<660	660
Benzo(a)anthracene	56-55-3	<330	330
bis(2-Ethylhexyl)phthalate	117-81-7	<330	330
Chrysene	218-01-9	<330	330
Di-n-Octyl Phthalate	117-84-0	<330	330
Benzo(b)fluoranthene	205-99-2	<330	330
Benzo(k)fluoranthene	207-08-9	<330	330
Benzo(a)pyrene	50-32-8	<330	330
Indeno(1,2,3-cd)pyrene	193-39-5	<330	330
Dibenz(a,h)anthracene	53-70-3	<330	330
Benzo(g,h,i)perylene	191-24-2	<330	330

* Analyte detected but amount present is less than the Quantitation Limit.

Analytical Method: SW 846 Method 8270
Analyst: J. Sima

Table 16. Concentrations of Pesticides/PCB's in sediments of Upper Fish Lake.

PRIORITY POLLUTANTS
PESTICIDES/PCBS
ANALYTICAL RESULTS

ATEC Lab No. 81848

Analyte	CAS Number	Concentration (ug/kg)	Quantitation Limit (ug/kg)
Aldrin	309-00-2	<300	300
Dieldrin	60-57-1	<300	300
Chlordane	57-74-9	<300	300
4,4'-DDT	50-29-3	<300	300
4,4'-DDE	72-55-9	<300	300
4,4'-DDD	72-54-8	<300	300
Endosulfan I	959-98-8	<300	300
Endosulfan II	33213-65-9	<300	300
Heptachlor epoxide	1024-57-3	<300	300
alpha-BHC	319-84-6	<300	300
beta-BHC	319-85-7	<300	300
gamma-BHC (Lindane)	58-89-9	<300	300
delta-BHC	319-86-8	<300	300
PCB-1242	53469-21-9	<300	300
PCB-1254	11097-69-1	<300	300
PCB-1221	11104-28-2	<300	300
PCB-1232	11141-16-5	<300	300
PCB-1248	12672-29-6	<300	300
PCB-1260	11096-82-5	<300	300
PCB-1016	12674-11-2	<300	300
Toxaphene	8001-35-2	<300	300
Endosulfan Sulfate	1031-07-8	<300	300
Endrin	72-20-8	<300	300
Endrin Aldehyde	53494-70-5	<300	300
Heptachlor	76-44-8	<300	300

* Analyte detected at levels below Quantitation Limit
Analytical Method: EPA Method 8080

Table 17. Concentrations of Metals, Cyanide and Total Phenols in Sediments of Upper Fish Lake.

Metals, Cyanide and Total Phenols	Concentration (mg/kg) Top 12 Inches of Sediment	Quantitation Limit (mg/kg)	Method No. SW 846
Antimony	7.5	5.0	7020
Arsenic	<1.0	1.0	7060
Beryllium	0.5	0.5	7090
Cadmium	<0.5	0.5	7130
Chromium	1.1	0.5	7190
Copper	<0.5	0.5	7210
Lead	3.5	0.5	7420
Mercury	<0.4	0.4	7471
Nickel	3.2	0.5	7520
Selenium	<1.0	1.0	7740
Silver	<0.5	0.5	7760
Thallium	10	1.0	7840
Zinc	11	0.5	7950
Cyanide	<0.25	0.25	9010
Phenols	<0.25	0.25	8270 (Sum Totals)

Watershed Modeling

Introduction

As mentioned earlier, two principal streams flow into the Fish Lake system (Figure 39). Fish Creek drains a 3.5 square mile area north and west of Upper Fish Lake and enters the lake along its northern shore. Turnbell Engineering calculated relative land use for this segment of the Fish Lake watershed as: forest (10%), rowcrops (54%), pasture (14%), urban (0.2%), and wetland (21%). The latter is comprised chiefly of Cranberry Marsh, a peat bog that has undergone extensive draining since 1968 associated with a peat mining operation. As such, this area no longer functions as a wetland in the true meaning of the term.

Mill Creek drains a 1.28 square mile area immediately to the east of the Fish Creek drainage basin and enters Upper Fish Lake along the northern shore immediately east of Fish Creek. This stream has been extensively channelized. Land use breakdown includes forest (10%), rowcrops (46%), pasture (10%), urban (4%), and wetland (29%). No major streams are found in the remainder of the Fish Lake watershed (2.90 square miles). This section of the watershed consists of all lands east and west of both Upper and Lower Fish lakes. A percentage breakdown of land use for this area is: forest (2%), rowcrop (43%), pasture (8%), urban (14%), and wetland (21%). Upper Fish has 106 residences, 49 of which are occupied year round, while the values for Lower Fish are 113 and 59, respectively.

Computer Model

Turnbell Engineering used the SEDIMOT II computer model developed by the University of Kentucky for their watershed modeling effort. This model uses William's Modified Universal Soil Loss Equation (MUSLE) in conjunction with a special subroutine (SLOSS) for watershed segments displaying varying slopes or channel flow. An operator's manual was not supplied to the author.

The modeling effort of Turnbell Engineering was restricted to the Fish Creek segment of the total watershed, and this drainage basin was considered broadly representative of the Fish Lake watershed as a whole. The Fish Creek drainage basin was subdivided into branches, junctions and structures for use in model construction. Criteria for boundaries between these subcomponents were ground slope, soil type, land use, and subwatershed geometry.

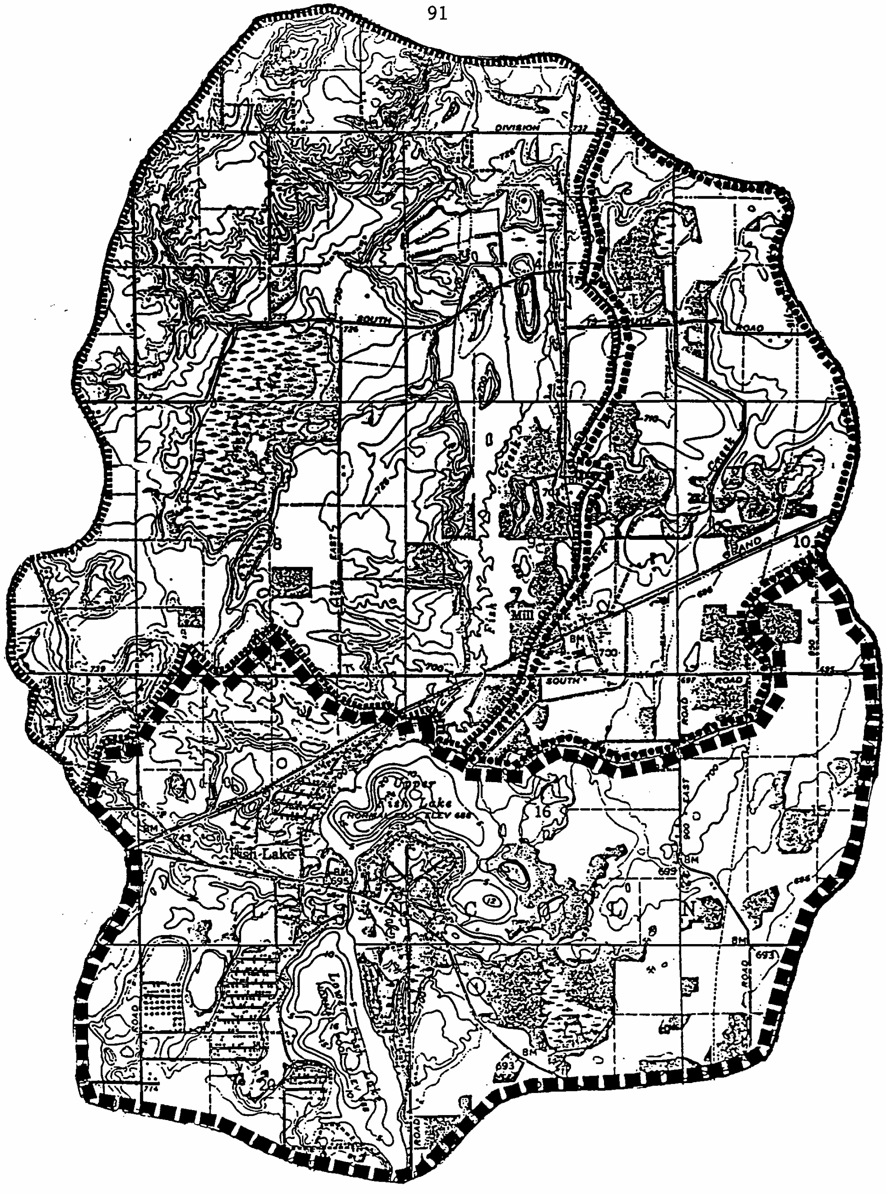


Figure 39. Watershed Map for the Fish Lake System.

Model Input Parameters

The design storm used in model construction was the one year return frequency storm (annual storm). The Division of Water (DNR) reported this storm for the Fish Lake area to be 2.4 inches for a 24 hour duration. A USDA, SCS type II rainfall distribution was used. Remaining hydrological input data including concentration, travel times, Muskingom's K, and Muskingom's X were computed according to instructions provided in the computer model manual.

Grain size distribution for the major soils in the area, Tracey-Chelsea Series (1 and 2) and Adrian-Houghton-Edwards Series (3 and 4), were obtained from the LaPorte County Soil Survey as follows:

Size (mm)	% Finer			
	1	2	3	4
4.7600	95	100	100	100
2.0000	85	85	100	95
0.4200	70	65	100	80
0.0740	40	50	85	45
0.0050	15	5	10	5
0.0001	0	0	0	0

Additional soil related data included:

Specific Gravity	2.60
Coefficient for Distributing Sediment Load	1.50
Submerged Bulk Gravity	1.25

Soil erodibility factors for the various soil types were provided by the LaPorte County SCS office and used to prorate an overall erodibility factor for each segment of the Fish Creek drainage basin.

Land use related parameters were C (control), P (practice), CN (SCS curve number) and surface condition (disturbed, agricultural, forest). C factors for nonagricultural land uses were obtained from Applied Hydrology and Sedimentology for Disturbed Areas by B.J. Barfield, R. C. Warner, and C.T. Haan. C factors for agricultural land uses and P factors were supplied by the LaPorte County SCS office. Curve numbers were derived from SCS Technical Release 55. Finally, surface conditions were determined from aerial photographs with field verification.

Model Results

Model results for the Fish Creek drainage basin are provided in Table 18. The conclusion of Turnbell Engineering was that currently 744 tons of sediment would be deposited

Table 18. Sediment Loading to Upper Fish Lake from Fish Creek Watershed (Tons).

	Existing Conditions		Improved Land Use	
	Sub Shed	Combined	Sub Shed	Combined
$J_1B_1S_1$	38.30		28.29	
$J_1B_2S_1$	18.30		18.30	
$J_2B_1S_1$	4.64	61.19	4.64	51.18
$J_2B_2S_1$	393.42		85.35	
$J_2B_2S_2$	19.86	413.22	14.45	99.78
$J_2B_2S_3$	0.60	413.65	0.60	100.34
$J_3B_1S_1$	109.18	583.96	63.91	215.42
$J_3B_1S_2$	0.05	583.96	0.05	215.30
$J_3B_2S_1$	58.97		9.39	
$J_4B_1S_1$	32.77	674.93	22.99	247.54
$J_4B_1S_2$	4.78	679.27	0.72	248.09
$J_4B_1S_3$	64.90	743.85	28.12	276.09

at the mouth of Fish Creek under existing conditions for the annual storm of the model. The model predicted that the 296 acre subbasin (Cranberry Marsh) utilized for the peat mining operation currently contributes 55 tons (7%) of the total sediment delivery during the annual storm of the model. It was suggested, however, that if no-till farming was practiced in all areas of highly erodable soil, this figure could be reduced to 276 tons, a 66% reduction in sediment delivery.

Turnbell Engineering, in their 15 March 1989 draft final report for Fish Lake, presented a photocopy of a 1972 aerial photograph showing a well defined delta at the mouth of Fish Creek and a less well defined delta at the mouth of Mill Creek. Both creeks appeared to be delivering sediment to Upper Fish Lake.

The modeling effort by Turnbell Engineering assumes that the Fish Creek drainage basin is broadly representative of the entire Fish Lake watershed. This may not be a valid assumption. The previously discussed stream chemistry clearly demonstrated that Fish Creek and Mill Creek were different, especially during May. Under normal rainfall conditions, such differences may be even greater.

The model treated Cranberry Marsh as a typical wetland. This is anything but the case. In fact, the area has been drained extensively for a peat mining operation. Assumptions for the model that apply to typical wetlands do not apply to such disturbed areas. I am currently working on a problem in Finland evaluating the impact of draining of peat bogs on downstream lake chemistry and biology. Simola (1983) clearly demonstrated that peatland drainage clearly increased the delivery of inorganic sediment to downstream lakes, and Simola and Lodenius (1982) showed that drainage of peatland also increases delivery of mercury to lakes as a result of dry out and oxidation of peat. A similar phenomenon appears to be occurring in Florida where wetland drainage has been suggested as the source for excessively high mercury in fish tissue collected throughout the state.

Conclusions and Recommendations

As early as 1969, the DNR noted excessive submergent macrophyte growth in Fish Lake and recommended a weed control program to improve the fishery. Problems with excessive macrophytes have continued to plague the lake to the present in spite of a major management effort by local residents. A number of lines of evidence suggest that water quality declined progressively during the early 1970's. Gizzard shad, a plankton feeding fish characteristic of eutrophic lakes, appeared for the first time in 1973 and was in such numbers that DNR instituted a selective eradication program in the fall of that year. Further evidence for a reduction in water quality during this period was the progressive reduction in Secchi disk transparency.

The greatest change in water quality occurred abruptly following 1975. The first report of water column anoxia during June was in 1976 and such early summer oxygen depletion has been noted in all surveys since this time. The importance of gizzard shad increased markedly after 1975 to constitute over 35% of total fish weight by 1978. Increased shad is a clear sign of advancing eutrophication.

The eutrophication index of all three basins of the Fish Lake system (Mud, Upper Fish, Lower Fish) remained essentially unchanged between 1975 and 1988 although total phosphorus values appear to have declined somewhat since the mid 1970's. It must be kept in mind, however, that such indices are based on water column parameters and do not take into account aquatic macrophytes and their ability to trap phosphorus before it enters the water column.

There is a clear trends towards increasing water quality southward through the Fish Lake system. Although the 1988 database was sparse, I feel that this trend reflects the fact that the weed growth of Upper Fish Lake is able to trap nutrients entering the lake from the watershed thus reducing the nutrient availability to Lower Fish. Given that both Upper and Lower Fish Lakes are comparably developed residentially, such a line of reasoning suggests that residential nutrient loading is minuscule compared with that contributed by the watershed.

The fact that water quality declined progressively during the early 1970's and especially after 1975-76 argues against residential development as the prime cause. A majority of the shoreline was developed prior to this period, and I could find no evidence for a massive population increase that could account for observed water quality changes during this period.

From the investigation conducted by Turnbell

Engineering, it is extremely difficult for me to make sound management recommendations for the lake basins. This is especially true regarding the principal management problem, aquatic macrophytes. No data were provided on macrophyte species composition, aerial extent of growth, and depth distribution of biomass. Without knowing such details of the problem, a long term solution can not be formulated. Given that macrophytes appear to be trapping nutrients in Upper Fish, we must be able to estimate how much area of weeds should be left at stream mouths to maximize this important plant function.

The Turnbell Engineering draft report suggested that both Fish Creek and Mill Creek were contributing sufficient sediment to Upper Fish Lake as to form deltas at both stream mouths. Unfortunately, they did not attempt to investigate the extent of basin infilling nor whether such infilling was serious enough to warrant sediment removal or similar management option. In order to address this important question, it is recommended that a new bottom map be made for the Fish Lake system for comparison with those of the early 1950's in order to estimate both the extent of basin infilling and potential costs for its management.

The Turnbell Engineering watershed modeling effort concentrated on Fish Creek. There is no reason to suppose that Fish and Mill Creeks should behave similarly. One particular problem is how Cranberry Marsh was addressed. This is not a typical wetland, but has been extensively drained for a commercial peat mining operation. As previously stated, such drainage of peat areas can have a profounded impact on receiving bodies of water. Fish Creek is a complicated system below this operation, consisting of small ponds, wetlands, and stream channel. The rather limited database on water chemistry collected by Turnbell Engineering was suggestive that the creek is able to reduce some of the impact of the peat mining operation by the location of County Road 200 S. This should be examined in detail. A detailed study of the peat mining operation on Fish Lake is needed. It is recommended that additional ground truth data be collected for inclusion into a watershed model.

It is apparent that both Fish Creek and Mill Creek are contributing substantial sediment and nutrient loads to the Fish Lake system. It is my recommendation that sites be located for wetland construction near the mouths of both of these streams and detailed plans be drafted. Several wetlands are present in the Fish Lake watershed that could possibly be expanded upon as part of any plan to reduce watershed release of nutrients. Special care should be taken, however, to leave these natural wetlands intact in order to facilitate their role in nutrient retention and wildlife preservation.

The Fish Lake watershed is in need of implementation of soil conservation measures. Such measures could include pasture land-hay field rotation, conservation tillage practices, and a 10 year commitment to put land in grass or trees. Currently there are no "T by 2000" structural projects underway for any watershed segment. It is essential that current management practices be supplemented and applied to additional areas of the watershed. Additional methods for structural (diversions, grass waterways) and cultural (reduced tillage) land treatment practices must be examined to reduce erosion within the watershed.

Any future design phase should include further detailed watershed modeling including analysis of the impact of the peat mining operation on lake water quality. Given the inadequacy of the current database, detailed examination of both the macrophyte and basin infilling problems must be considered an integral part of design phase work. Without such information a cost effective long term management plan for both the lake and its watershed can not be formulated.

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